Glycative Stress Research

Online edition : ISSN 2188-3610
Print edition : ISSN 2188-3602
Received : July 10, 2014
Accepted : August 2, 2014
Published online : September 30, 2014

Original Artcle

Prevention of postprandial hyperglycemia by the combination of a staple food and a side dish

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Abstract

***Objective*:** The degree of postprandial blood glucose level elevations varies depending on the choice of staple food; foods with a low glycemic index (GI) produce a slow elevation of postprandial blood glucose level, and blood glucose elevations can be slowed by adding dietary fiber to staple food. This study was conducted to assess the effects of various combinations of a staple food (carbohydrate) and a side dish on changes in postprandial blood glucose level, with the aim to develop a method of reducing glycation stress.

***Results*:** In the subjects exhibiting a blood glucose elevation of AUC ≥5,000 after eating cooked rice, the postprandial blood glucose levels observed after taking each of 9 staple foods were compared. A comparison of postprandial blood glucose levels following ingestion of udon (thick Japanese wheat flour noodle) + side dish revealed that ingestion of udon + salad produced slower blood glucose level elevations and a smaller AUC than udon taken alone ($p = 0.029$). Udon + soft boiled egg produced a smaller AUC than udon taken alone ($p = 0.023$). Udon supplemented with dietary fiber produced a smaller AUC than cooked rice ($p = 0.040$). Udon topped with braised meat and eggplant produced a smaller AUC than udon taken alone ($p = 0.034$). A comparison of postprandial blood glucose levels following ingestion of cooked rice + side dish revealed that a bowl of rice topped with braised meat and eggplant produced a smaller AUC than cooked rice taken alone ($p < 0.001$). The AUC of a bowl of rice topped with braised meat and eggplant was similar to that of udon topped with braised meat and eggplant ($p > 0.1$).

***Conclusion*:** A combination of a staple food and a side dish may be more effective than low-GI foods in suppressing glycation stress. Not only choice of low-GI foods, but also choice of side dishes is important to the suppression of meal-related glycation stress.

***KEY WORDS*:** glycemic index, postprandial hyperglycemia, glycation stress, dietary fiber

Introduction

The phenomenon in which reducing sugars such as glucose bind to protein non-enzymatically to form glycoproteins is known as glycation. Glycation stress refers to a form of stress on the body caused by a load of reducing sugar or aldehyde[1,2]. As an aging risk factor, glycation stress can serve as a promoter of skin aging, diabetic complications, and other conditions. Available methods of glycation stress reduction include the suppression of hyperglycemia, the suppression of glycation reactions, and the degradation and excretion of glycation reaction products.

We previously assessed the effects of choice of staple food and the addition of dietary fiber on changes in postprandial blood glucose levels, showing that adding dietary fiber in advance suppresses blood glucose level elevations after meals[3]. However, the staple food cooked rice tends to produce greater elevations of blood glucose levels than pasta; there may be much room for improving the way of eating cooked rice in relation to other foods. Before starting the present study, we hypothesized that blood glucose level elevations could be suppressed by taking a staple food and a side dish in combination. In addition, provided that the difference in postprandial blood glucose level among different staple foods is lessened by taking a staple food and a side dish in combination, a glycation stress suppressing effect may be achieved by combining a staple food, even if chosen freely, with an appropriately chosen side dish. In the present study, we assessed the effects of choice of staple food and its combination with various side dishes on changes in postprandial blood glucose levels, with the aim to develop a method of reducing glycation stress from the viewpoint of suppression of hyperglycemia.

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Methods

Subjects

Subjects were recruited from among those with relevance to the Department of Anti-Aging Medicine, Doshisha University Faculty of Life and Medical Sciences., as in the previous study [3]. The subject inclusion criteria comprised healthy persons aged 20 years or older who did not meet any of the following exclusion criteria: those with food or drug allergy, pregnant or lactating women, patients under treatment with medication or follow-up, patients with the diagnosis of diabetes mellitus, patients with a pronounced cardiopulmonary functional disorder, patients on therapeutic medication for hypertension, persons with a past history of gastrointestinal surgery, and persons suspected of having infectious disease. Other subjects judged by the investigator as being inappropriate for inclusion in the study were also excluded from the study.

The study population comprised 19 subjects with relevance to Anti-Aging Medical Research Center, Doshisha University Faculty of Life and Medical Sciences (9 males and 10 females, age 30.3 ± 12.0 years, BMI 20.8 ± 2.5). These subjects provided written consent to participate in the study after being given a full explanation of the study.

Protocol for blood glucose test

A blood glucose test was performed according to the unified protocol established by the Japanese Association for the Study of Glycemic Index (JASGI) [4] as reported previously [3].

On the day before the test, excessive exercise, taking meals after 8:00 p.m, surfeit, overdrinking, and staying up late at night were prohibited. If the subject felt ill on the day before the test, or prior to or during the test, the test was postponed or terminated.

On the day of the test, the reference diet and each test food were taken over a period of 5-10 minutes, with about 30 chews per mouthful. Blood glucose was measured at 15 (2nd time), 30 (3rd time), 45 (4th time), 60 (5th time), 90 (6th time), and 120 minutes (7th time) after the start of food ingestion (taking each test food). Each subject measured glucose levels using a glucose meter for self monitoring (GLUCOCARD MyDia, ARKRAY, Inc., Kyoto).

Test foods

The reference diet and test foods used in the present study are listed in ***Table 1***. Nutrient contents in some of these foods were calculated using the Standard Tables of Food Composition in Japan 2010 [5].

Handmade udon and ingesting indigestible dextrin-blended udon (udon supplemented with dietary fiber) were used as staple foods, with cooked rice serving as the reference diet, as reported in the previous study [3]. These materials were supplied by Hanamaru, Inc. (Chuo-ku, Tokyo, Japan). Thereafter, the influence of side dishes on blood glucose levels were assessed using udon with a soft boiled egg (Japanese common name “ontama udon”), vegetable udon (Japanese common name “salad udon”), a bowl of rice topped with braised meat and eggplant (mabonasu) (cooked rice + mabonasu), and udon topped with mabonasu

Table 1. Staple food consumption and nutrients in test food items

Food items	Staple food Consumption	Energy (kcal)	Protein (g)	Lipids (g)	Carbohydrates (g)	Dietary fiber (g)	Amount of carbohydrates other than dietary fiber
Cooked rice 200g + furikake (seasoned dried condiments for sprinkling over rice)	200	347	5.6	1.2	75.2	0.6	74.6
Kakeudon (handmade udon + soup stock)	270	346	8.6	1.1	75.9	2.3	73.6
Handmade udon (small-serving)	210	273	7.0	0.9	59.5	1.7	57.8
Udon with a soft boiled egg (handmade udon + soft boiled egg)	210	371	13.9	7.8	61.2	1.7	59.5
Salad udon (handmade udon + vegetables)	210	395	9.5	6.6	71.5	4.4	67.1
Udon supplemented with dietary fiber	250	349	7.1	1.5	77.1	2.6	74.5
Bowl of rice topped with braised meat and eggplant (cooked rice + mabonasu)	180	498	18.0	11.1	79.0	4.2	74.8
Udon topped with braised meat and eggplant (handmade udon + mabonasu)	230	501	18.5	11.7	80.7	5.9	74.8

Udon: thick Japanese wheat flour noodle. Udon with a soft boiled egg: commonly called “ontama udon. Braised meat and eggplant: mabonasu.
Numerical figures for food items shown in black were calculated using the Standard Tables of Food Composition in Japan 2010 [5].
Numerical figures for food items shown in red were calculated using the nutritional facts indicated on the respective labels.

(udon supplemented with dietary fiber + mabonasu), which were selected from among recipes recommended by the collaborating udon manufacturer.

The amount of carbohydrates other than dietary fiber in each test food was set at 75 ± 10 g in order to correspond to the 75 g amount of carbohydrates other than dietary fiber for the 75 g oral glucose tolerance test (OGTT) in common use for diagnosing diabetes mellitus, except for kakeudon (wheat noodles served hot in broth), ontama udon, and salad udon, taken alone, which were used exactly in the amounts indicated on their labels to reflect the recipes shown by the udon manufacturers. The amount of carbohydrates other than dietary fiber was obtained by subtracting the amount of dietary fiber from the amount of carbohydrates.

Of the foods used in the experiments, udon and udon supplemented with dietary fiber were supplied by Hanamaru, Inc. Packed cooked rice (Sato No Gohan; Sato Foods Co., Ltd., Niigata, Japan) was used as reference diet. Retort-packed sauce packs (Mabonasu No Moto; Marumiya, Suginami-ku, Tokyo, Japan) were used for braised meat and eggplant.

Statistical analyses

The 0-minute value was subtracted from the blood glucose level measured over time after eating each test food to obtain Δblood glucose level; the largest change in the level observed up to 120 minutes after the start of ingestion was considered as the maximum blood glucose level change. Using these parameters, the area under the blood glucose elevation curve (AUC) was calculated. Data obtained were statistically analyzed by the Mann-Whitney U-test for significant differences between 2 groups and Tukey's multiple comparison test among 3 groups or more, using the SPSS statistical analysis software. A two-sided p-value of less than 5% was considered to indicate a significant difference.

Ethical Considerations

The present study was conducted in compliance with the ethical principles of the Declaration of Helsinki (Note of Clarification added at the 2004 World Medical Association General Assembly in Tokyo) and Japan's Act on the Protection of Personal Information, and with reference to the Ministerial Ordinance on Good Clinical Practice (GCP) for Drug (Ordinance of Ministry of Health and Welfare No. 28 of March 27, 1997) and the Ethical Guidelines for Epidemiological Research established by Japan's Ministry of Health, Labour and Welfare, and Ministry of Education, Culture, Sports, Science and Technology. The present study was conducted after examination and approval for the ethics and appropriateness of the study at a meeting of the Doshisha University Ethics Committee for Scientific Research Involving Human Subjects (Approval number # 1228).

Results

A comparison was made between kakeudon and ontama udon (kakeudon + soft boiled egg) and between kakeudon and salad udon (kakeudon + vegetables). Ontama udon produced no significant difference in maximum blood glucose level change, with a 27% smaller AUC ($p = 0.029$, ***Figs. 1 and 2***), compared with kakeudon. Salad udon tended to have smaller maximum blood glucose level changes ($p = 0.056$), with a 28% smaller AUC ($p = 0.023$, ***Figs. 3 and 4***), compared with kakeudon.

Influence of a combination of cooked rice or udon supplemented with dietary fiber and a shared side dish on blood glucose levels

When comparing cooked rice and udon supplemented with dietary fiber, udon supplemented with dietary fiber had a smaller maximum blood glucose level change of 17 mg/dL ($p = 0.013$), with a 20% smaller AUC ($p = 0.046$, ***Figs. 5 and 6***), than cooked rice.

A bowl of rice topped with braised meat and eggplant (mabonasu) produced a 15 mg/dL lower maximum blood glucose level change ($p = 0.046$) and a 28% smaller AUC ($p < 0.001$, ***Figs. 7 and 8***) than cooked rice taken alone.

When comparing udon topped with mabonasu and udon supplemented with dietary fiber taken alone, no significant difference in maximum blood glucose level change was found, and the AUC was smaller by 28% with udon topped with mabonasu than with udon supplemented with dietary fiber ($p = 0.034$, ***Figs. 9 and 10***).

In both the maximum blood glucose level change and AUC, no significant difference was found between a bowl of rice topped with mabonasu and udon topped with mabonasu (***Figs. 11 and 12***).

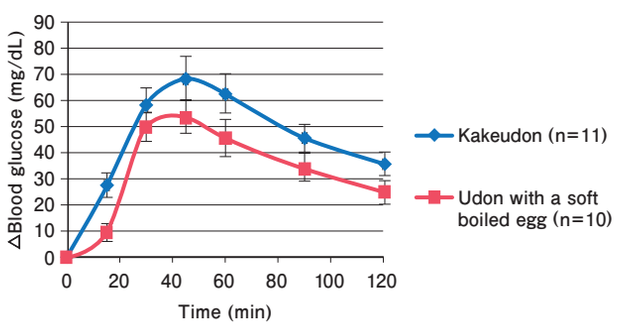

Fig.1. **Blood glucose level changes after ingestion of kakeudon or udon with a soft boiled egg (ontama udon).**

For maximum blood glucose level changes, no significant difference was found, Mann-Whitney U-test. Bar indicates standard error mean.

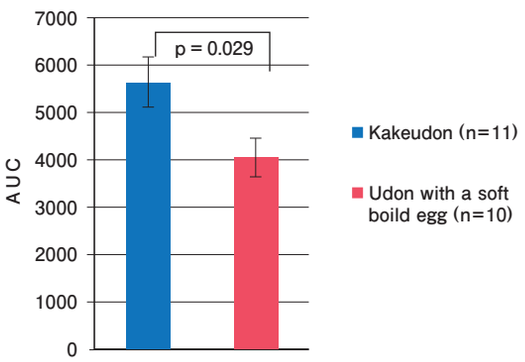

Fig.2. **AUC after ingestion of kakeudon or udon with a soft boiled egg (ontama udon).**

Mann-Whitney U-test. Bar indicates standard error mean.

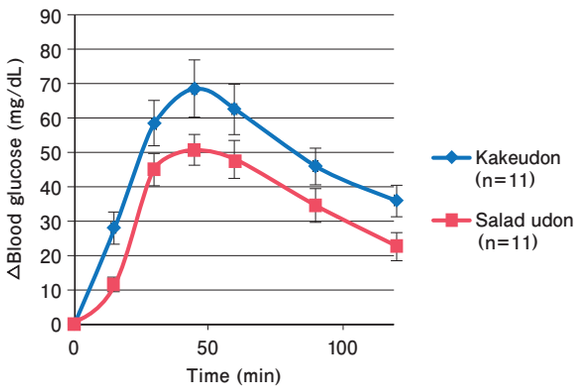

Fig.3. **Blood glucose level changes after ingestion of kakeudon or salad udon.**

For maximum blood glucose level changes, $p < 0.1$; kakeudon vs salad udon, Mann-Whitney U-test. Bar indicates standard error mean.

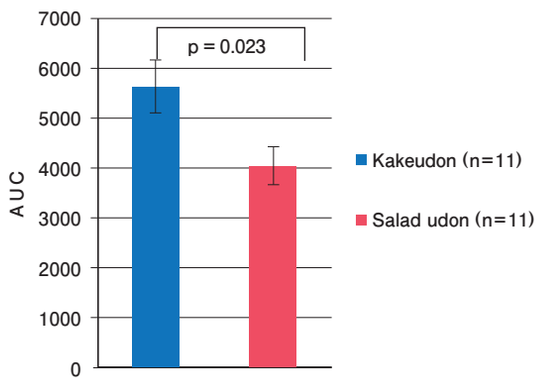

Fig.4. **AUC after ingestion of kakeudon or salad udon.**

Mann-Whitney U-test. Bar indicates standard error mean.

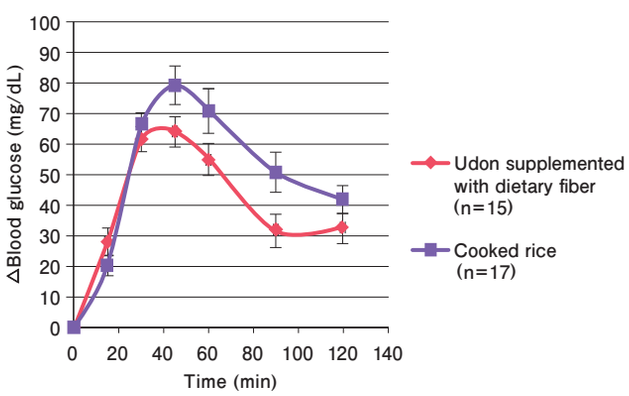

Fig.5. **Blood glucose level changes after ingestion of cooked rice or udon supplemented with dietary fiber.**

For maximum blood glucose level changes, $p < 0.05$: cooked rice vs udon supplemented with dietary fiber, Mann-Whitney U-test. Bar indicates standard error mean.

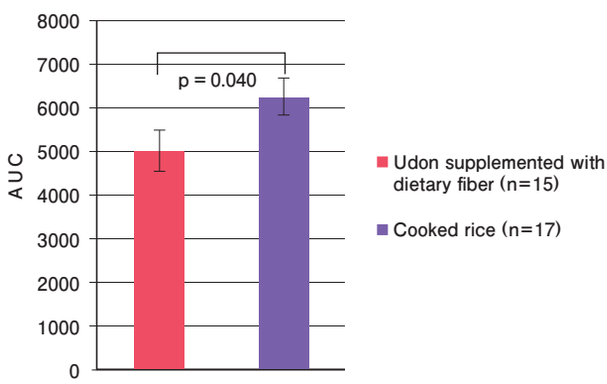

Fig.6. **AUC after ingestion of cooked rice or udon supplemented with dietary fiber.**

Mann-Whitney U-test. Bar indicates standard error mean.

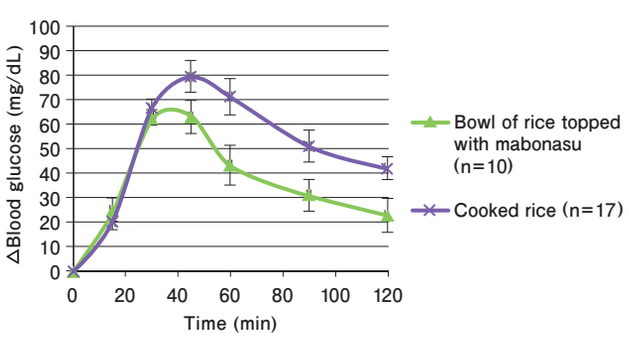

Fig.7. **Blood glucose level changes after ingestion of cooked rice or bowl of rice topped with braised meat and eggplant (mabonasu).**

For maximum blood glucose level changes, $p < 0.05$; cooked rice vs. bowl of rice topped with braised meat and eggplant, Mann-Whitney U-test. Bar indicates standard error mean.

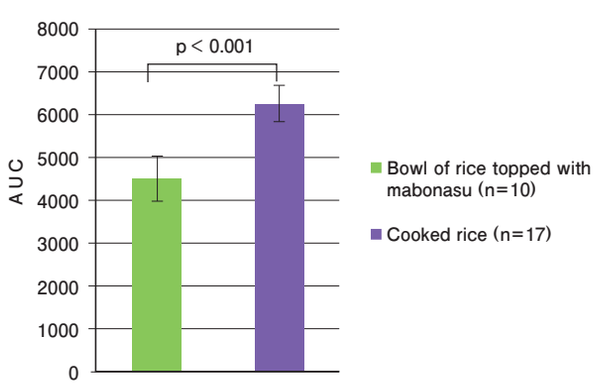

Fig.8. **AUCs after ingestion of cooked rice or bowl of rice topped with braised meat and eggplant (mabonasu).**

Mann-Whitney U-test. Bar indicates standard error mean.

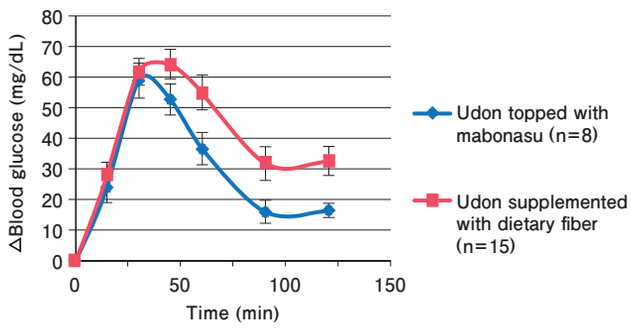

Fig.9. **Blood glucose level changes after ingestion of udon supplemented with dietary fiber or udon topped with braised meat and eggplant (mabonasu).**

For maximum blood glucose level changes, no significant difference was found, Mann-Whitney U-test.

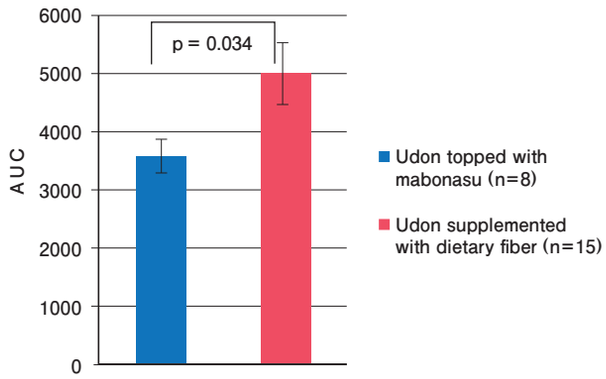

Fig.10. **AUCs after ingestion of udon supplemented with dietary fiber or udon topped with braised meat and eggplant (mabonasu).**

Mann-Whitney U-test.

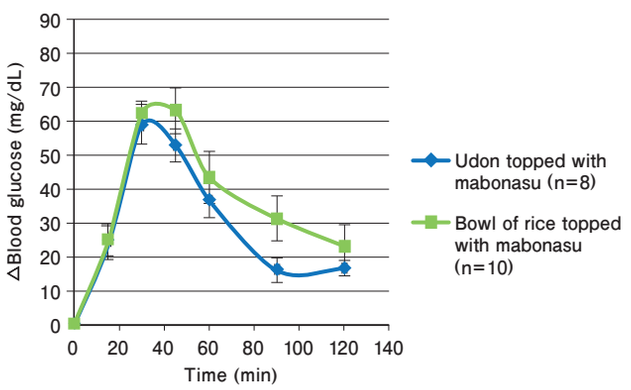

Fig.11. **Blood glucose level changes after ingestion of bowl of rice topped with braised meat (mabonasu) or eggplant and udon topped with braised meat and eggplant (mabonasu).**

For maximum blood glucose level changes, no significant difference was found, Mann-Whitney U-test.

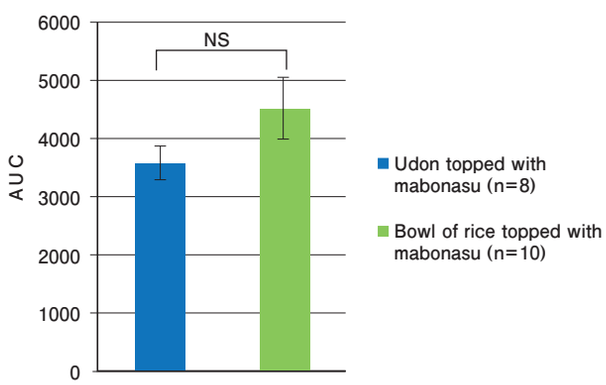

Fig.12. **AUCs after ingestion of bowl of rice topped with braised meat and eggplant (mabonasu) or udon topped with braised meat and eggplant (mabonasu).**

Mann-Whitney U-test.

Discussion

In the comparative study of different staple foods reported previously, bread and pasta tended to produce lower values of both maximum blood glucose level change and AUC than cooked rice. Although a combination of cooked rice and a soup containing dietary fiber did not suppress changes in postprandial blood glucose levels, the addition of dietary fiber to udon was shown to lessen the elevation of blood glucose levels after meals. In the present study, the effects of the choice of side dish taken in combination with cooked rice on postprandial blood glucose level elevations were assessed.

The salad udon experiment showed that the amount of carbohydrates other than dietary fiber was greater by nearly 10 g in salad udon than in kakeudon. Despite this fact, concurrent ingestion of salad and udon revealed a blood glucose level reducing effect. It has already been reported that blood glucose level elevations are more largely suppressed by taking vegetable salad before taking cooked rice [6,7].

Dietary fiber contained in vegetables is known to delay sugar absorption by increasing viscosity of the content in the upper gastrointestinal tract via its gelation, and influencing the content movement rate as well as digestion and absorption in the gastrointestinal tract [8], and to suppress postprandial blood glucose level elevations by causing the secretion of glucagon-like peptide-1 (GLP-1), an insulin secretagogue that promotes insulin secretion via mechanical stimulation of the gastrointestinal tract [9-11].

In the salad udon experiment in the present study, the greater suppression of postprandial blood glucose level elevation with salad udon than with kakeudon is attributable to an effect of vegetables. The same experiment also demonstrated that a dietary fiber effect of vegetables was obtained by taking the vegetables concurrently with a staple food.

The smaller AUC obtained with udon with a soft boiled egg (ontama udon) than with kakeudon is attributable to the influence of the proteins and lipids contained in the eggs. It is believed that elevations of postprandial blood glucose levels were suppressed by the influence of proteins and lipids. Especially lipids influence gastric smooth muscle movement via gastrointestinal tract hormone and the vagus nerve to reduce the gastric emptying rate [12], thus slowing the blood glucose elevation after meals.

By adding braised meat and eggplant (mabonasu) as a side dish to each staple food (cooked rice and udon supplemented with dietary fiber), postprandial blood glucose level elevations were suppressed compared with staple food alone. In addition to the lipid effect [12], olive oil possesses GLP-1 secretagogue activity [13]; therefore, the vegetable dietary fiber and meat proteins and lipids in mabonasu, and the lipid in the olive oil used for cooking the test food, can be considered to have acted in a multiplex way.

In addition, the carbohydrates other than dietary fiber contained in the retort-packed sauce for braised meat and eggplant (mabonasu) primarily comprise starch and are absorbed in the form of glucose. The vegetables contain only approximately 5 g of carbohydrates other than dietary fiber. Therefore, it is unlikely that the observed suppression of postprandial blood glucose level elevations was attributed to the fact that the carbohydrates other than dietary fiber contained in braised meat and eggplant were different from those in other side dishes.

Because GI values are calculated from AUC, foods that produce a sharp elevation and reduction of blood glucose level have low GI values because of their low AUC. As stated with regard to kakeudon and buckwheat noodles (soba) in our previous report [3], the AUC is lower for buckwheat noodles, whereas the maximum blood glucose level change is lower for udon. Because glycation is reportedly more likely to proceed at blood glucose levels of 160 mg/dL or more, it is also important to suppress the maximum blood glucose level change in order to suppress glycation stress. For this reason, to suppress glycation stress, it is necessary to choose food items taking into account not only GI value, but also the maximum blood glucose level change

It was found that postprandial blood glucose levels were suppressed by eating a staple food and vegetables in combination, and by eating a staple food and a side dish in combination. When comparing cooked rice and udon supplemented with dietary fiber, cooked rice was found to be more likely to cause postprandial hyperglycemia, and no significant difference was found in the postprandial blood glucose level between a bowl of rice topped with braised meat and eggplant (mabonasu + cooked rice) and udon topped with braised meat and eggplant (mabonasu + udon supplemented with dietary fiber). These findings suggest that when the same side dish is combined with different staple foods, the differences in postprandial blood glucose level among the staple foods decrease. It is therefore concluded that a glycation stress suppressing effect more than that of low-GI foods can be obtained by combining a staple food and a side dish.

It was found that in suppressing glycation stress, the choice of side dish is more important than choice of staple food. Since the choice of staple food may be related to mental stress due to the inability to eat any staple food freely, we believe that it is readily acceptable for daily dietary life to choose a staple food freely, and take it in combination with appropriate side dishes.

It is recommended that the side dishes taken contain dietary fiber, proteins, and lipids in a good balance, and they should also incorporate a vegetable possessing anti-glycation activity. In the present study, braised meat and eggplant (Mabonasu) was used to this end. Western-type eggplant and spinach, which were contained in the braised meat and eggplant examined, have been reported to have anti-glycation activity [14]. Many vegetables are known to show anti-glycation activity. We hypothesized that glycation stress could further be suppressed by using anti-glycation vegetables as an ingredient of side dishes.

Conclusion

A combination of a staple food and side dishes may be more effective than low-GI foods in suppressing glycation stress. While it is an approach to suppressing glycation stress from meals to choose a staple food from among low-GI foods such as pasta, as well as udon supplemented with dietary fiber, even high-GI foods such as cooked rice are expected to be more effective than low-GI foods when combined with an appropriately chosen side dish.

Acknowledgments

A presentation of this study was made at the 13th Scientific Meeting of Japanese Society of Anti-Aging Medicine (Yokohama; June 2013), and it received the Best Poster Award selected by high school students. Test food samples were provided by Hanamaru, Inc..

Statement of conflict of interest

The authors have no conflicts of interest related to this study to declare.

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