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Original Article

Preparation of contemporary dishes and a functional drink using Japan's heirloom vegetable, *Katsura-uri*

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ABSTRACT

Background: The fruit of *Katsura-uri*, traditionally used in the preparation of pickles in Japan, is facing an extinction crisis. In addition to the traditional dishes prepared from *Katsura-uri*, alternative dishes using the fruit should be devised to increase consumer demands for the protection of the heirloom vegetable. We attempted designing new *Katsura-uri* contemporary dishes and assessed the application of *Katsura-uri* juice as a functional drink without raising blood glucose levels.
Methods: Cooking experiments were conducted with *Katsura-uri* in its ripening stages, based on the advice from a licensed chef and a registered dietitian in Japan. In the questionnaire-based sensory evaluation, consumer acceptability of *Katsura-uri* juice was assessed. The blood glucose levels were measured after healthy volunteers consumed the juice.
Results: We demonstrated six new *Katsura-uri* dishes. In the questionnaire-based sensory evaluation of *Katsura-uri* juice, the assessment values for taste and fragrance were high. In human trials, the levels of incremental area under the curve and glucose spike were significantly lower after consumption of *Katsura-uri* juice, as compared to those after consumption of muskmelon juice.
Conclusion: *Katsura-uri*-containing contemporary dishes and juice would help continue the consumption of the vegetable. Based on the results of the questionnaire, we also concluded that the use of *Katsura-uri* as a functional drink without raising blood glucose levels is superior to its use as contemporary dishes. These findings provide useful strategies to protect *Katsura-uri* from extinction.

1. Introduction

Traditional foods are generally consumed as a part of the culture and history in limited areas of a region. However, consumer demands have shifted from heirloom vegetables to the new varieties of vegetables, resulting in a decrease in the farming area devoted to cultivation of the traditional varieties and, in some cases, termination of commercial cultivation. In the modern world, consumer demands are focused on foods with functional properties, such as possessing low-calorie content, achieving slow increase in blood glucose level, and lowering blood triglyceride level [1,2]. We recently proposed a new strategy to protect *Katsura-uri* (Japan's heirloom pickling melon, *Cucumis melo* var. *conomon*) (Fig. 1A), using its juice as a functional drink to demonstrate its ability to prevent obesity and diabetes. *Katsura-uri* was grown and preserved by a single septuagenarian farmer in Japan in 2011 and thus faces an extinction crisis (Fig. 1B) [3].

Traditionally, immature and midripened fruits of *Katsura-uri* are used in the preparation of pickles, such as *kasu-zuke*. These are prepared by soaking the fruit for several months in the lees of Japanese liquor and Japanese sweet seasoning liquor [4,5].

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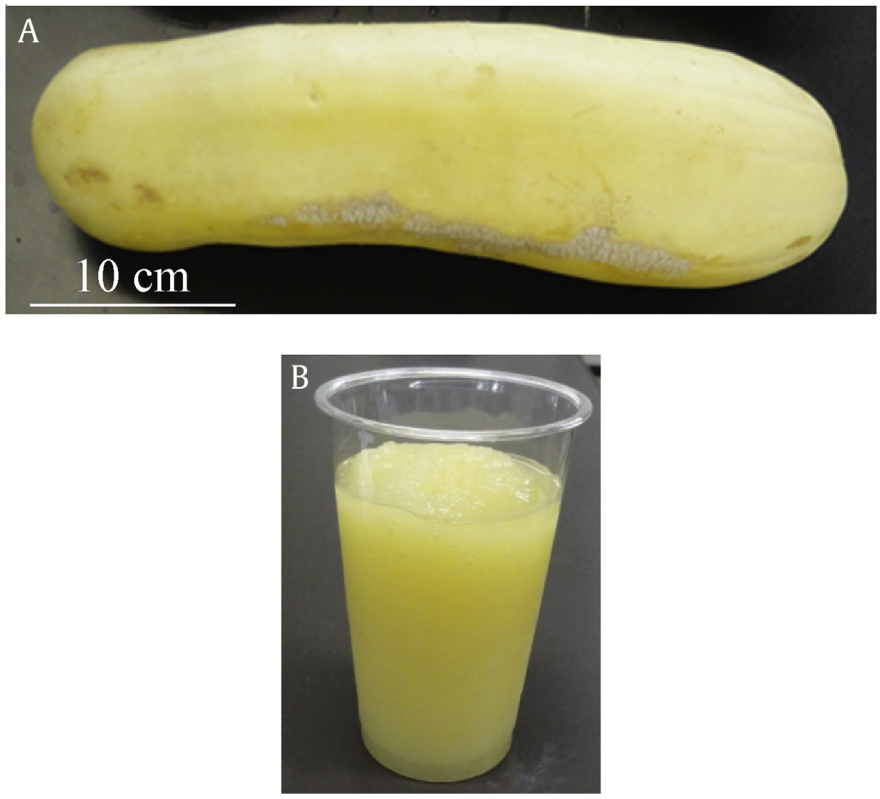

Fig. 1. *Katsura-uri* fruit in its fully ripened stage in two forms. (A) The whole fruit. (B) A novel low-calorie juice.

However, consumer demands for *kasu-zuke* have decreased, resulting in a decrease in the number of farmers willing to cultivate *Katsura-uri*. In addition to the traditional use of *Katsura-uri* in *kasu-zuke* preparation, alternative dishes using the fruit during all its ripening stages (immature, midripened, and fully ripened) should also be introduced to increase consumer demands. These dishes would also be valuable for propagating traditional customs by people involved in the *Gion-Matsuri* festival (one of the three major festivals in Japan and is hosted by *Yasaka-jinja* shrine every July 1–31 in Kyoto). Since the symbol of the shrine is similar to a sliced section of a cucumber, people involved in the festival traditionally avoid eating cucumber during the festival, which is called *kyuri-dachi*, and often eat *Katsura-uri* instead. However, most people in Kyoto are unaware of this custom and do not follow it. To create awareness about the local food and history of Japanese culture in future generations, formulating recipes that involve the fruit of *Katsura-uri* would be helpful because, presently, the number of *Katsura-uri* dishes being offered is limited. Therefore, we designed some contemporary dishes containing *Katsura-uri* using different cooking styles (e.g., raw, deep-frying, sauté, and boiling) and seasonings, based on the advice of a licensed chef and a registered dietitian in Japan.

To further our knowledge of this heirloom vegetable, we also prepared a novel low-calorie juice from fully ripened *Katsura-uri*. This beverage would be especially useful and relevant in present times considering the increase in obesity and diabetes cases worldwide. The *Katsura-uri* juice is a palatable juice possessing low-calorie properties (small amounts of fructose, glucose, and sucrose) and a muskmelon-like fragrance on addition of zero-calorie sweeteners [3]. Thus, *Katsura-uri* juice has the potential to serve as a functional food for obese individuals and patients with diabetes. Moreover, sensory evaluation by 20 panelists showed high values for taste and muskmelon-like fragrance in *Katsura-uri* juice sweetened with zero-calorie sweeteners [3]. However, sensory evaluation by large-scale panel was not performed to assess large-scale consumer acceptability. A human trial was also not conducted to assess blood glucose levels after drinking the juice. Therefore, we accomplished sensory evaluation of *Katsura-uri* juice with the help of 531 consumers and measured the blood glucose levels when healthy volunteers drank the juice in this study.

In this study, we report the preparation of six new *Katsura-uri* dishes and a *Katsura-uri* functional drink for the prevention of obesity and diabetes. This could also prove to be a useful strategy to protect Japan's heirloom vegetable from extinction by increasing its demand as a healthy low-calorie fruit.

2. Materials and methods

2.1. Plant samples

Katsura-uri was harvested in July and August from 2010 to 2014 in an open-field culture system at the Kyoto Prefectural Agricultural Research Institute, Kameoka, Kyoto, Japan. Muskmelon (*Cucumis melo* var. *reticulatus*; cultivar name Raiden red) was purchased from a wholesale market in Kyoto, Japan. Immature, midripened, and fully ripened *Katsura-uri* fruits were stored at 4°C for designing the dishes. Fully ripened *Katsura-uri* fruits were washed with water and longitudinally cut into four pieces of the same size. Each piece was peeled, and the seeds were removed. The pieces were vacuum-packed in plastic bags and stored at −25°C for the human trials, which involved a taste test and measurement of blood glucose levels. Muskmelon was treated in a similar manner; it was washed with water, cut into eight pieces of the same size, peeled, had its

seeds removed, vacuum-packed in plastic bags, and stored at −25°C for the human trials.

2.2. Preparation of Katsura-uri dishes

Cooking experiments were conducted using *Katsura-uri* at all the ripening stages. Six dishes were created based on the advice from a licensed chef (from a Japanese restaurant "Kushikura") and a registered dietitian in Japan (from a self-company "Concierge of food and agriculture Graine").

2.3. Preparation of juices

Katsura-uri juice for the sensory evaluation and measurement of blood glucose levels was prepared as follows: 100 g of frozen fruit (stored at −25°C) was thawed partially, chopped, and mixed in an electric automatic mixer (TM840, Tescom Co. Ltd., Tokyo, Japan) with 2.25 g of zero-calorie sweeteners (ingredients: erythritol, aspartame, acesulfame K; product name: Pal Sweet diet) supplied by Ajinomoto Co. Inc. (Tokyo, Japan). Muskmelon juice for measurement of blood glucose levels was prepared as follows: 100 g of frozen fruit (stored at −25°C) was thawed partially, chopped, and mixed in an electric automatic mixer.

2.4. Sensory evaluation of Katsura-uri juice

A total of 531 (199 male, 271 female, 61 unknown) panelists, with ages ranging from 10 to 90 years and from 8 different places, assessed the *Katsura-uri* juice sweetened with zero-calorie sweeteners. For the determination of consumer acceptability, panelists drank the *Katsura-uri* juice (50 g) and answered two questions by rating on a 5-point scale. The questions were as follows:

1. "Choose one of the following that applies to the taste of *Katsura-uri* juice: excellent, good, fair, poor, or very poor".
2. "Choose one of the following that applies to the muskmelon-like fragrance of *Katsura-uri* juice: very strong, strong, fair, poor, and very poor".

2.5. Measurement of the blood glucose level

Ten healthy volunteers (5 men and 5 women, aged 22–25 years) were recruited from Kyoto Prefectural University. Their recruitment was approved by the Ethics Committee of Kyoto Prefectural University. Profiles of human volunteers in height, weight, and body mass index are shown in Table 1. The volunteers were asked to fast but were allowed to consume water, from 22:00 PM on the previous day to the end of the trial. At 10:00 AM on the day of the trial, the peripheral blood glucose level was measured using an automated portable glucose meter (Glutest Sensor and Glutest Every; Sanwa Kagaku Kenkyusho, Nagoya, Japan) from blood samples obtained by a finger-stick sampling. Then, the volunteers drank the *Katsura-uri* juice (240 g), and the blood glucose levels were measured 15, 30, 45, 60, 90, and 120 min after consumption. Blood glucose levels were plotted, and the incremental area under the curve (AUC) was calculated using the trapezoid rule [6]. On two different days, tests to estimate the blood glucose levels were conducted in participants after they consumed a solution containing 25 g glucose (Trelan-G, Ajinomoto Pharmaceuticals Co. Ltd., Tokyo, Japan) and a solution containing 240 g of muskmelon juice, instead of 240 g of *Katsura-uri* juice. The muskmelon juice (240 g) contained 25 g of carbohydrates (according to the Standard Tables of Food Composition in Japan 5th revised and enlarged edition; 10.4 g of carbohydrate in 100 g of muskmelon) [7]. Therefore, we used 25 g of glucose solution, equivalent to 25 g of carbohydrates contained in 240 g of muskmelon juice, and 240 g of *Katsura-uri* juice, equivalent to the total weight of the muskmelon juice (240 g).

Table 1
Sex, height, weight, and body mass index of human volunteers.

Volunteer	Sex	Height (cm)	Weight (kg)	Body mass index (kg/m^2)
A	Female	168	51	18.1
B	Male	172	65	22.0
C	Male	177	78	24.9
D	Female	151	39	17.1
E	Female	160	48	18.8
F	Female	154	48	20.2
G	Female	160	52	20.3
H	Male	173	52	17.4
I	Male	178	65	20.5
J	Male	183	64	19.1
Average ± SEM	–	168 ± 3.4	56 ± 3.6	19.8 ± 0.7

SEM, standard error of mean.

2.6. Statistical analyses

Analysis of variance followed by Fisher's protected least significant difference method were applied for the measurement of blood glucose levels. The results were considered significantly different for $p < 0.05$.

3. Results

3.1. Preparation of Katsura-uri dishes

One *Katsura-uri* dish, *gomafumi-ae*, was prepared as advised by a national registered dietitian in Japan (Fig. 2A). The recipe for the dish is as follows: immature *Katsura-uri* fruits were washed with water and peeled, and the seeds were removed. The flesh of the fruit cut into 1-cm thick slices, a carrot cut into fine strips, and an eggplant cut into semicircular slices were boiled. Ham and cucumber were cut into fine strips and semicircular slices, respectively. These constituents were dressed with vinegar blended with soy sauce, sugar, sesame oil, and sesame seeds. Five *Katsura-uri* dishes using different cooking styles and seasonings were prepared based on the advice from a licensed chef. The recipes for the dishes are as follows: *Tosa-ae*, salt-rubbed midripened *Katsura-uri* fruit was sprinkled with *katsuobushi* (dried bonito flakes) on the entire surface (Fig. 2B); *agedashi*, deep-fried fully ripened *Katsura-uri* fruit soaked in *dashi* (fish-broth with soy sauce) (Fig. 2C); *ikomi*, minced chicken stuffed into hollowed-out fully ripened *Katsura-uri* fruit (Fig. 2D); *kimpira*, sautéed finely cut strips of midripened *Katsura-uri* fruit with soy sauce and sugar (Fig. 2E); *kanten-yose*, mashed and boiled fully ripened *Katsura-uri* fruit made into a jelly using *dashi* and agar (Fig. 2F).

3.2. Sensory evaluation of Katsura-uri juice

Katsura-uri juice was prepared from the fully ripened fruit mixed with zero-calorie sweeteners, and it was evaluated by 531 panelists. In the evaluation of taste of the *Katsura-uri* juice, the responses of excellent and good were 52.0% and 35.6%, respectively (Fig. 3A). In the evaluation of muskmelon-like fragrance in the juice, the responses of very strong and strong were 37.9% and 52.4%,

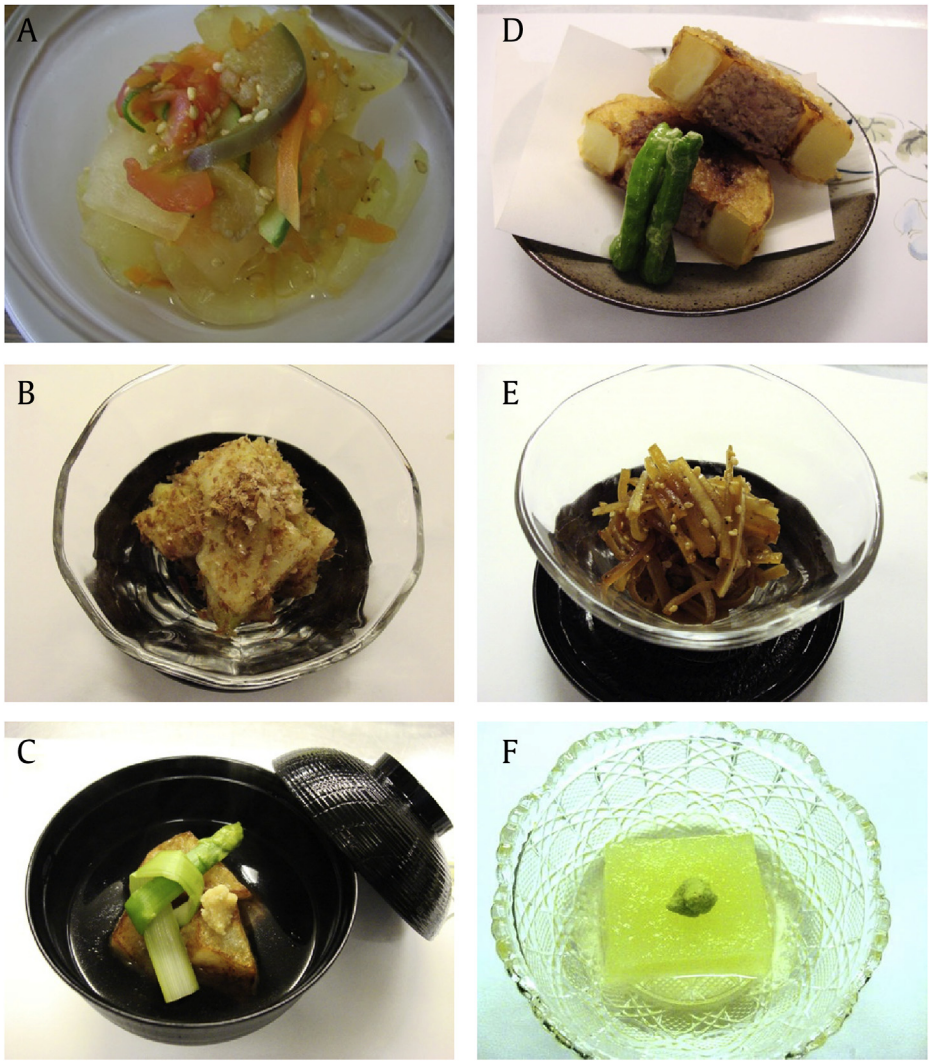

Fig. 2. *Katsura-uri* dishes. (A) *Gomafumi-ae*, boiled *Katsura-uri* fruit dressed in vinegar blended with soy sauce, sugar, sesame oil, and sesame seeds. (B) *Tosa-ae*, salt-rubbed *Katsura-uri* fruit sprinkled with *katsuobushi* on the entire surface. (C) *Age-dashi*, deep-fried *Katsura-uri* fruit soaked in *dashi*. (D) *Ikomi*, minced chicken stuffed into *Katsura-uri* fruit hollowed-out in a semicircular shape. (E) *Kimpira*, sautéed finely-cut strips of *Katsura-uri* fruit with soy sauce and sugar. (F) *Kanten-yose*, mashed, boiled *Katsura-uri* fruit jellified with *dashi* and agar.

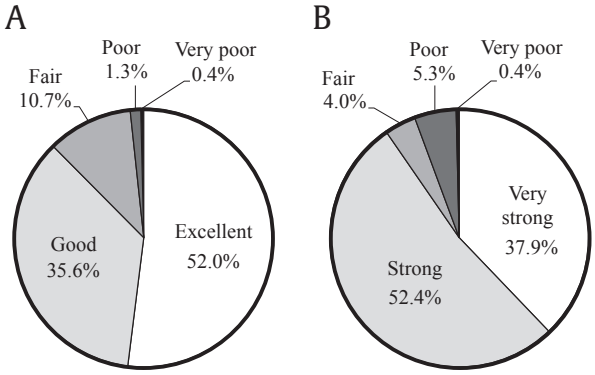

Fig. 3. Sensory evaluation of *Katsura-uri* juice by 531 panelists. (A) Evaluation of taste: "Choose one of the following that applies to the taste of *Katsura-uri* juice: excellent, good, fair, poor, or very poor". (B) Evaluation of flavor: "Choose one of the following that applies to the muskmelon-like fragrance of *Katsura-uri* juice: very strong, strong, fair, poor, or very poor".

respectively (Fig. 3B). The overall result of the sensory evaluation by 531 panelists was high for taste and fragrance.

3.3. Measurement of the blood glucose level

Blood glucose levels of 10 healthy volunteers were measured after drinking solutions containing 25 g of glucose, 240 g of *Katsura-uri* juice, and 240 g of muskmelon juice. All 10 volunteers completed the experiment. The AUC range of 10 volunteers who consumed the solution of 25 g glucose ranged between 32 and 130 h mg/dl. The panels of A to J in Fig. 4 are organized in the order of the AUC levels, A (highest) to J (lowest), per glucose administration. The blood glucose levels of the 10 volunteers were below 100 mg/dl in the three drink trials after fasting, and all the volunteers were healthy (Fig. 4).

The average blood glucose level of the 10 volunteers was plotted (Fig. 5A). Blood glucose levels started increasing immediately after administration of the three drink trials. However, the blood glucose response curve was apparently different among the three trials. The

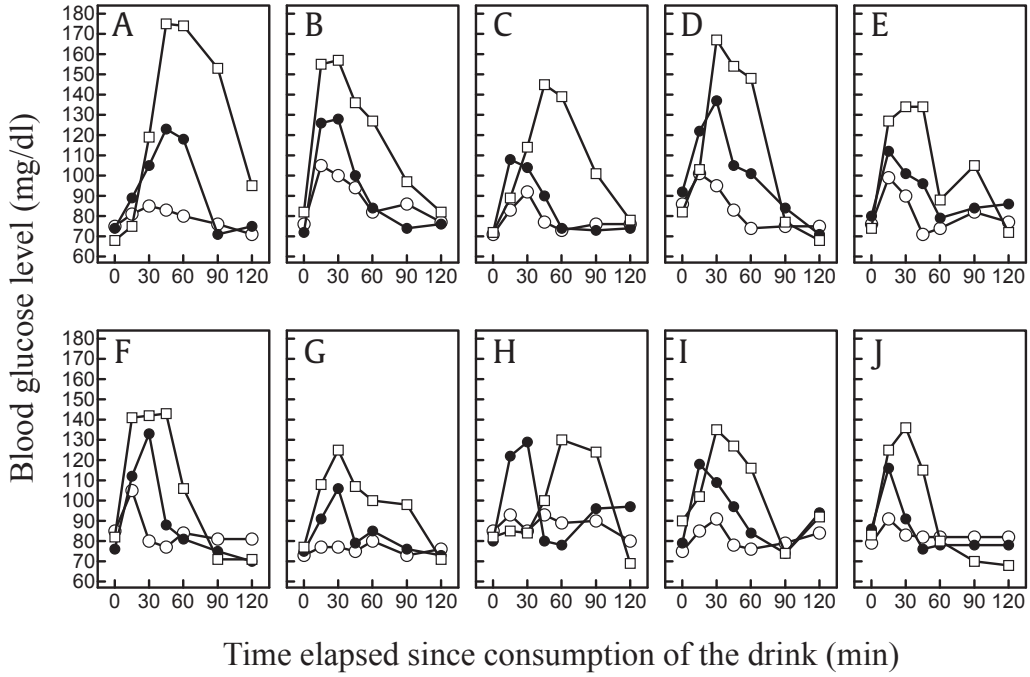

Fig. 4. Profiles of blood glucose response curve in 10 healthy volunteers, each represented by a letter after oral administration of three different drinks at three different trial experiments. (□) 25 g of glucose, (●) 240 g of muskmelon juice, and (○) 240 g of *Katsura-uri* juice.

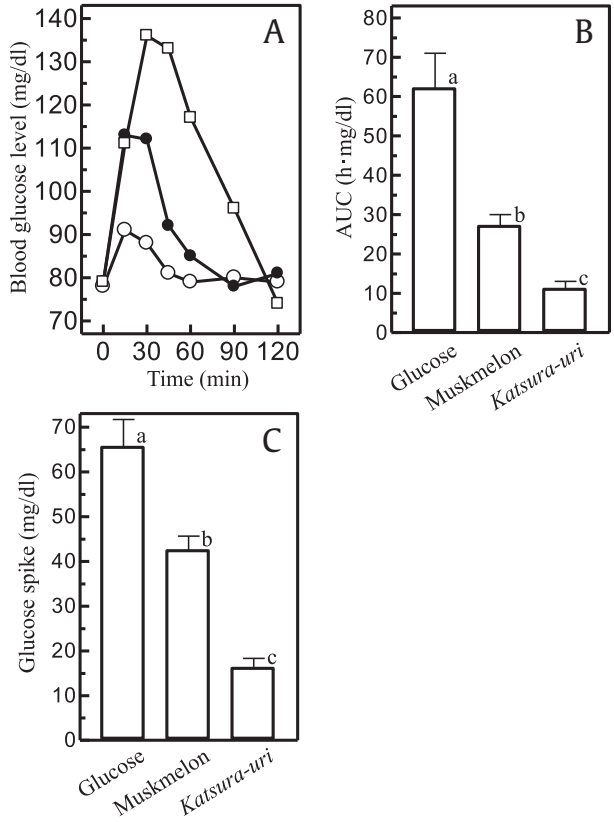

Fig. 5. Blood glucose response curves, area under blood glucose response curve (AUC), and glucose spike after oral administration of three drinks. (A) Blood glucose response curve for (□) 25 g of glucose, (●) 240 g of muskmelon juice, and (○) 240 g of *Katsura-uri* juice. (B) AUC levels. (C) Glucose spike response. Each value represents an average (±SEM) of 10 volunteers. Values, followed by different letters (among a, b, and c), are significantly different ($p < 0.05$) by multiple comparison tests of Fisher's protected least significant difference. SEM, standard error of mean.

level of AUC was found to be 62 ± 9 h mg/dl in the glucose trial (Fig. 5B). However, the AUC levels were 27 ± 3 h mg/dl and 11 ± 2 h mg/dl in the muskmelon and *Katsura-uri* trials, respectively. The AUC level was significantly lower after consumption of *Katsura-uri* juice, as compared with that after consumption of muskmelon juice ($p < 0.05$).

The levels of the glucose spike (the difference between the baseline glucose level and the peak) were also different among the three trials (Fig. 5C). The level was significantly lower after consumption of *Katsura-uri* juice, as compared to that after consumption of muskmelon juice ($p < 0.05$).

4. Discussion

For creating awareness in the next generation regarding the local fruit *Katsura-uri*, which is deeply connected with the *Gion-Matsuri* festival, we provided six contemporary cooking recipes using the fruit *Katsura-uri* (Fig. 2). These dishes are useful to people who traditionally eat *Katsura-uri* during the *Gion-Matsuri* festival, instead of cucumber. Some dishes have been prepared based on consumer demands at a restaurant, where the licensed chef (provided advice for the preparation of dishes in this study) works in Kyoto city. Currently, very few dishes involve the use of *Katsura-uri*, and few people know the custom that people involved in the *Gion-Matsuri* festival avoid eating cucumber during the festival. Therefore, such public campaigns are helpful to generate awareness among the public and also to protect the extinction of *Katsura-uri* in future.

The total consumption of *Katsura-uri* through these preparations will still be insufficient as the fruit will only be consumed during the 1-month festival of *Gion-Matsuri*. Therefore, additional strategies are needed to increase its demand among consumers. Increase in the consumer demand of *Katsura-uri* will cause farmers to produce *Katsura-uri* sustainably and protect *Katsura-uri* from extinction. At present, vegetables that contribute to improving public health are preferably produced in farms in Japan. Although

heirloom vegetables have not undergone selective breeding, the direction of farming methods is gaining importance. We proposed a new strategy to protect *Katsura-uri* aimed at using its juice as a functional drink to prevent obesity and diabetes [3]. We surveyed the efficacy of fully ripened *Katsura-uri* as a low-calorie juice, which would be especially beneficial considering the increase in obesity and diabetes in the modern world. Sensory evaluation of *Katsura-uri* juice (sweetened with zero-calorie sweeteners) by 20 panelists showed a high satisfaction level in taste and fragrance in our previous study [3]. In this study, we adopted the same procedure of sensory evaluation done with the help of 531 panelists; the number of panelists was increased to validate the results of the previous study. The same high satisfaction level was achieved in our current experiments, irrespective of sex, age, and medical history of diabetes (Fig. 3). In human trials, the *Katsura-uri* juice can minimize postprandial blood glucose levels and the subsequent glucose spike in healthy humans (Figs. 4 and 5). Thus, we demonstrated *Katsura-uri* juice as an acceptable and novel functional drink that can be potentially useful for minimizing human postprandial blood glucose levels. The juice can also be considered as a separate dish and different from the repertoire of six dishes of *Katsura-uri* offered in this study for people participating in the *Gion-Matsuri* festival.

Low amount of sugars in fully ripened *Katsura-uri* fruit (2.8 g/100 g) lowered the blood glucose levels in healthy volunteers (Figs. 4 and 5) [3]. Lowering of blood glucose levels has been reported to reduce the risk of type 2 diabetes and cardiovascular diseases among healthy individuals [8,9]. Thus, this juice would be useful for patients suffering from diabetes, a disease that affects about 415 million people worldwide [10]. Therefore, we plan to measure the blood glucose levels in diabetic participants after consistent *Katsura-uri* fruit juice consumption, which could potentially improve their quality of life in the future. Based on the data of consistent consumption of *Katsura-uri*, we concluded that the use of *Katsura-uri* juice as a functional drink, which does not raise blood glucose levels, is superior to its use in the prepared *Katsura-uri* dishes. These findings might provide a strategic model to protect the crop from extinction in present diet habits.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgments

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