Protection of Kyo-yasai (heirloom vegetables in Kyoto) from extinction: a case of Sabaka-daikon (Japan’s heirloom white radish, Raphanus sativus) in Maizuru, Japan

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ABSTRACT

As a general background, Sabaka-daikon, one of the heirloom vegetables in Kyoto, ceased its commercial cultivation in the late 1960s at north Kyoto, leading to an extinction crisis. We review the activities of the local residents to revive the commercial cultivation of Sabaka-daikon from 2010. We also discuss the significance of the information on the health benefits of local foods in motivating local residents to protect local foods from extinction. To verify this hypothesis, we analyzed the health benefits of local foods using the traditional cultivation methods and the marketing strategies of vendors. We confirm that the information on the health benefits of local foods is a key factor in motivating local residents to protect local foods from extinction. As a result, the primary factors for the revival of Sabaka-daikon in Maizuru city include the passion of farmers, measures undertaken by the local administration, and the marketing strategies of vendors. The secondary factor is the fact that one primary factor (passion of farmers) coincides on a time axis with the other two factors (administrative measures and marketing strategies of vendors). Wide individual differences in the anticarcinogenic compound, 4-methylthio-3-butenyl isothiocyanate, were observed, likely due to the variable genome of Sabaka-daikon. In conclusion, the results imply that the information on the health benefits of local foods is a key factor in motivating local residents to protect local foods from extinction. Revival of this heirloom vegetable would contribute to the diversification of local foods, and to the preservation of those foods and the cooking knowledge for future generations. As Sabaka-daikon variety has some races in variation of 4-methylthio-3-butenyl isothiocyanate production, a race with a fixed amount of 4-methylthio-3-butenyl isothiocyanate should be established to guarantee added health benefits of Sabaka-daikon.

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1. Introduction

Kyoto was the seat of the imperial court of Japan from 794 (the start of the Heian period) to 1868 (the end of the Edo period). During this period, many novel varieties of vegetables were gathered as an offering to the emperors. Because of this historical period, current-day Kyoto Prefecture has an extensive collection of various heirloom vegetables that have been termed “Kyo-yasai” [1]. The heirloom vegetables, Kyo-yasai are frequently referred to as “heirloom vegetables in Kyoto” and “traditional vegetables in Kyoto” in scientific language; or sometimes referred to as “Kyo-no-dento-yasai” (in Japanese pronunciation) and “Brand-Kyo-yasai” in the context of a less scientific language as described below. The seeds of Kyo-yasai have been preserved using traditional cultivation methods, and typically Kyo-yasai vegetables have more distinctive flavors than conventional vegetables do. Since the 1970s, consumers have, however, preferred milder flavors and odors over those of new varieties of heirloom vegetables, and thereby some Kyo-yasai with strong flavors have greatly reduced in number, and are thus facing an extinction crisis. In order to preserve Kyo-yasai for the next
generation, administrative measures were initiated in Kyoto Prefecture in 1974 to protect these heirloom vegetables from extinction, and to collect their various seeds from farmers in order to preserve them at the Horticultural Division of the Kyoto Prefectural Agriculture, Forestry, and Fisheries Technology Center (Kameoka, Japan). In 1988, Kyoto Prefecture defined the heirloom vegetables in Kyoto by the name Kyo-no-dento-yasai, which might have originated before 1686 (the end of the Edo period). Kyo-no-dento-yasai included bamboo shoot, excluding fungi and ferns, and two varieties currently exterminated, Kori-daikon (Kori Japanese white radish) and Toji-kabu (Toji-temple turnip; Table 1) [2]. In 1989, Kyoto Prefecture also named heirloom vegetables as Brand-Yo-yasai, which reflects Kyoto’s image, and thus is a certificate of good quality, individuality, and superiority for outside Kyoto Prefecture, securing stable supply to the market (Table 1). In 1990, the nutritional values of Kyo-yasai were first reported as comparative amounts of vitamins and minerals in conventional vegetables by Kyoto Prefectural Institute of Public Health and Environment. Thereafter, in 1998, the biological effects of Kyo-yasai were first reported as comparative bioantimutagenicity of conventional vegetables [3]. Some Kyo-yasai varieties, Momoyoama-daikon (Japanese white radish, Raphanus sativus), Kamo-nasu (eggplant, Solanum melongena), Shishigatani-kabocha (pumpkin, Cucurbita moschata), and Katsu-ur-uri (pickling melon, Cucumis melo conomon), had higher antimutagenic potencies (a higher activity and higher yield) than other conventional vegetables as investigated using the Escherichia coli B/r WP2 assay [3,4].

Daikon (Japanese white radish, Raphanus sativus) is a Japanese vegetable. Among the 37 varieties of Kyo-no-dento-yasai, eight are daikon varieties (Table 1). Shogoin-daikon is also a Brand-Kyo-yasai, and is the most shipped type, in quantity, among the eight varieties of daikon. Shogoin-daikon cultivation was recorded in a Japanese picture book, Karaku-meisho-zue (1864; Fig. 1A). The picture book showed Shogoin-daikon (Chinese characters in Fig. 1B read “Shogoin”; to be spindle-shaped (Fig. 1C), but, interestingly, it is globular in the present day (Fig. 1D). Daikon varieties have been affected by consumer-driven preferences to decrease the strong pungent flavor, and have gradually disappeared from the market over the past 40 years in Japan. The pungent compound is 4-methylthio-3-butyl isothiocyanate (MTBITC). MTBITC was identified in 1982 as an antimicrobial compound [5]. However, the health benefit of MTBITC as a bioantimutagenic compound was first revealed in 2001 [6]. Because no other biological or health effects were identified for this compound between 1982 and 2001, there was no motivation for plant breeders to prevent the reduction in MTBITC levels in daikon. Breeding programs to reduce the pungency of this vegetable have been quite successful resulting in Aokubi-daikon, which is the most commonly used conventional daikon in Japanese cuisine. Ironically, the health benefit of MTBITC was revealed in 2001, which was after Aokubi-daikon was developed, produced, and distributed throughout Japan [6,7]. The anticarcinogenic activity of MTBITC was first reported in a newspaper in 2005, and the ability of this compound to reduce N-nitrosobis(2-oxopropyl)amine (BOP)-induced pancreatic carcinogenesis in hamsters was demonstrated in 2013 [8]. In 2016, its chemopreventive effect against esophageal carcinogenesis in rats was reported [9]. Such information of an added health benefit would increase the customer’s desire to buy daikon.

The commercial cultivation of Sabaka-daikon (Sabaka Japanese white radish, Raphanus sativus; Fig. 2A), one of the heirloom vegetables in Kyoto, was once terminated in the late 1960s in north Kyoto (Fig. 3), resulting in an extinction crisis. In this study, we
review activities undertaken by the local residents to revive the commercial cultivation of *Sabaka-daikon* from 2010, and demonstrate the use of *Sabaka-daikon* in increasing the vegetable's demand in traditional and contemporary dishes. We also discuss the significance of the knowledge on the health benefits of local foods in motivating local residents to protect local foods from extinction.

2. Materials and methods

2.1. Field interviews

We conducted face-to-face interviews with residents in Maizuru city, and the following cases were verified: (1) residents’ motivation to protect *Sabaka-daikon* from extinction; (2) morphology of *Sabaka-daikon* in crop fields; (3) achievements of *Sabaka-daikon* in cultivation at Maizuru city; (4) administrative measures in Maizuru city; and (5) public campaigns as administrative measures of Kyoto Prefecture and Maizuru city. The interview was administered with a key person among farmers in an attempt to revive *Sabaka-daikon* cultivation in Sabaka quarter (Cases 1–3), and employees of the agricultural extension section at Maizuru city municipal office (Cases 3–5).

2.2. Plant samples

*Sabaka-daikon* was harvested from November 2012 to February 2014 in an open field culture system at the Kyoto Prefectural Agricultural Research Institute (Kameoka city: longitude 135°34′ E, latitude 35°01′ N, altitude of 110 m, annual mean air temperature of 14.6°C, annual precipitation of 1,590 mm), Japan. Samples were cooled on harvest date in a refrigerator (4°C) and freighted overnight and transferred to Kyoto Prefectural University for immediate analysis within 2 days after being stored at 4°C. Nineteen *Sabaka-daikon* samples were used in this study. Samples were stored at 4°C until all analyses were performed on the day after harvest.

2.3. Individual differences in the production of MTBITC in *Sabaka-daikon*

*Sabaka-daikon* samples were washed with water and cut into four to 16 equal pieces longitudinally, and therefore, each piece represented the whole *daikon* for quantification of MTBITC. Then, these pieces of *daikon* samples was placed into an automatic *daikon* grater (CQM-V2, Toshiba Corp., Tokyo, Japan). The MTBITC production of each sample was determined 30 minutes after the grating step, because the maximum amount of MTBITC produced in grated *daikon* was observed 10 minutes after grating and did not change thereafter for another 50 minutes [7]. The grated *daikon* was incubated for 30 minutes at 25°C, then a 20-g aliquot of the grated *daikon* was filtered and the residue was extracted twice with 30 mL of distilled water. The water extracts were combined and diluted to 100 mL to prepare an aqueous crude sample solution and analyzed for MTBITC concentration. The aqueous sample (0.3 mL) was extracted three times, each with 150 μL of n-hexane. The n-hexane extracts were combined and MTBITC was measured by reverse-phase high performance liquid chromatography (Shimadzu, Kyoto, Japan) model LC-20AT with a SPD-20A UV detector. YMC ODS-H80 (ϕ4.6 × 150 mm) column was used for MTBITC analysis.
3. Results and discussion

3.1. Field interviews

A face-to-face interview with a key person among farmers, who wishes to revive Sabaka-daikon cultivation in the Sabaka quarter, and employees of agricultural extension section at Maizuru city municipal office, was performed at Maizuru city (Fig. 3; described in Field interviews section). All interviews were pioneering work conducted by authors, and the outcome is thus revealed initially in this study.

3.2. Resident’s motivation to protect the Sabaka-daikon from extinction

For the result of the interview, the great-grandfather of the key person interviewed also was a key person in Sabaka-daikon cultivation in the Sabaka quarter. As the commercial cultivation of Sabaka-daikon ended in the late 1960s, the key person knew his great-grandfather’s achievement in the dissemination of Sabaka-daikon in the Sabaka quarter. In May 2004, he obtained relevant knowledge regarding the health benefits of daikon by reading a newspaper article (The Japan Agricultural News, “Nihon-Nogyo-Shinbun” in Japanese pronunciation) describing the bioantimutagenic effect of the pungent ingredient of daikon, MTBITC [6].

In 2010, Maizuru city officers asked him to participate in the project of Sabaka-daikon cultivation revival. He accomplished copying his great-grandfather’s honorary certificate for horticultural achievement, and another two documents that he found from the back of the frame storing the certificate (Figs. 4A and 4B). One document described a list of attendances for an award ceremony of Sabaka-daikon cultivation originators (part a in Fig. 4A), and his great-grandfather’s name was ranked as a former committee head of the union (part b in Fig. 4A). Another document described the history of Sabaka-daikon cultivation at Sabaka quarter (part c in Fig. 4B). According to the document, in May 1901, cross-fertilization of the original variety of Sabaka-daikon with Makabe-daikon resulted in the second generation with a higher yield (part d in Fig. 4B). Cross-fertilization of the second generation with another variety produced at Owari (a former country name that lay around Nagoya city of the present day) successfully resulted in the third generation with higher yield and quality (part e in Fig. 4B). He realized that all breeding, by cross-fertilizing, had been performed by his great-grandfather, and gained relevant knowledge of health benefits of daikon, a motivation for the revival of Sabaka-daikon.

3.3. Morphology of Sabaka-daikon in crop fields

The morphology of Sabaka-daikon is shown in Fig. 2A. Sabaka-daikon has rosette leaves (extend horizontally on the ground such as dandelion leaves), whereas those of conventional Aokubi-daikon usually extend longitudinally (Fig. 2B). Thus, 250 pieces of Sabaka-daikon can be harvested in a 100-m² area, whereas 600–800 pieces of Aokubi-daikon can be harvested. The side-roots of Sabaka-daikon are larger than those of the conventional daikon. Its roots are firmer and have a lower moisture content than that reported for conventional Aokubi-daikon (Fig. 2C). When seeding in September, a longer period (150 days) is needed to harvest Sabaka-daikon, whereas conventional daikon can be harvested after 90 days.

3.4. Achievements of Sabaka-daikon in cultivation at Maizuru city, Japan

Sabaka-daikon originated in the Sabaka quarter (196 km², Maizuru, Kyoto) and has been cultivated from the Edo period of Japan (Fig. 3), and the gross area for the cultivation was 0.5 km² during the peak of its production (1.3Mkg) in the 1940s–1960s. In the 1940s–1950s, the daikon was covered up with rice straws for shipment (Fig. 5A), and the old-fashioned poster reveals that Sabaka-daikon was recognized as Maizuru’s principal local food for the public (Fig. 5B). The poster was printed around 1948–1951, because the federation captured in the poster existed from August 1948 to April 1951.

Sabaka-daikon has a more distinctive pungent flavor, and consumers preferred varieties with milder flavors over new varieties of...
daikon in the 1960s. Producers also preferred varieties that require fewer days to harvest and are easier to handle over conventional varieties of daikon. As a result, the cultivation of Sabaka-daikon vegetables has greatly reduced. To address this, the Kyoto Prefecture started administrative measures to protect heirloom vegetables in Kyoto, such as defining the heirloom vegetables in Kyoto by naming them Kyo-no-dento-yasai in 1988. Ironically, the commercial cultivation of Sabaka-daikon was terminated in the late 1960s.

3.5. Administrative measures in Maizuru city, Japan

Maizuru city office also started administrative measures to revive Sabaka-daikon cultivation from 2010. The seeds of Sabaka-daikon were provided by the Horticultural Division of the Kyoto Prefectural Agriculture, Forestry, and Fisheries Technology Center (Kameoka, Kyoto), and were sown on the crop field (100 m²) at the Sabaka quarter. The traditional cultivation methods were introduced to the farmers by agricultural extension officers from the agricultural extension organization of Kyoto Prefecture, Chutanhigashi-branch (a region in central Kyoto Prefecture), and seed raising was carried out for successive cultivation. In 2011, the seeds were sown on the crop field (800 m²) at the Sabaka quarter, and the area gradually increased to 1,500 m², 2,530 m², 3,490 m², 5,400 m², and 7,300 m² from 2012 to 2016, respectively.

3.6. Public campaigns as administrative measures of the Kyoto Prefecture and Maizuru city, Japan

The reason to increase the crop field area of Sabaka-daikon in Maizuru city is that Prefecture officers, city officers, and farmers established a project team, and collaborated to advertise Sabaka-daikon to the public. For instance, food tasting parties were held across restaurants in 2012 and school lunches, with nutritional education provided by the farmers, were held across elementary schools. The team also invited a person having relevant knowledge and experience, Professor Yasushi Nakamura of the Kyoto Prefectural University, including knowledge of the cancer preventive effects of daikon. In December 2012, the Food Culture Research Promotion Society of Sabaka-daikon was founded by the Kyoto Prefecture, Maizuru city, Japan Agricultural Cooperatives, Aeon Retail Co., Ltd., and farmers. In 2013, some retail stores of Aeon in Kyoto Prefecture started selling Sabaka-daikon on trial with its side dish sales for easy understanding by customers. In 2014, the Kyoto Prefecture distributed a booklet named “Restaurants provided delicious Kyoto’s cuisine” introduced Sabaka-daikon as a special issue.

Fig. 5. Traces of the past in Sabaka-daikon cultivation during 1940–1950s. (A) Sabaka-daikon covered up with rice straws during shipment; (B) old-fashioned poster for sales promotion for the public printed in 1948–1951.

Fig. 6. Science soup café “Shizuku-ya” supplies Sabaka-daikon soup, and relevant information regarding its health benefits. (A) Soup café along with Nishiki-ichiba market known as “Kyoto’s kitchen” newly opening in 2012; (B) exterior of the soup café; (C) soup café supplies four kinds of soups including Sabaka-daikon soup with the Sabaka-daikon displayed, which contributes to its public perception and recognition; (D) Sabaka-daikon soup with grated Sabaka-daikon in topping; (E) Sabaka-daikon soup garnished with its leaves chopped finely.
distributed to Kyoto Prefecture overall (24 pages including the front and the back pages). The information of Sabaka-daikon was focused on the taste in nostalgia and health benefits on one page of the booklet. Some restaurants in Kyoto were facilitated to offer Sabaka-daikon menu on trial and the result of the evaluation by restaurant owners showed high preference for the taste of Sabaka-daikon.

We also established a science soup café "Shizuku-ya" at the Nishiki-ichiba market known as “Kyoto’s kitchen” in the center of Kyoto city in 2012 (Figs. 6A and 6B) [10,11]. The soup café supplies Sabaka-daikon soup containing Sabaka-daikon and provides relevant information regarding the health benefits of daikon, thus contributing to public perception and recognition of the heirloom vegetables (Figs. 6C–6E). This, in turn, results in increased demand and subsequent motivation for the preservation of Sabaka-daikon. The recipe of the soup supplied by Shizuku-ya, was provided to a restaurant, “Fururu-farm” in Maizuru city, which started offering the soup to customers at Maizuru. In January 2017, Kyoto Prefecture, Maizuru city, and Japan Agricultural Cooperatives held an exchange meeting between producer and demander (i.e., dealer in pickles and restaurant owner) of Sabaka-daikon at Maizuru city with a food-tasting party held at the restaurant. This offered contemporary Sabaka-daikon dishes on trial (Fig. 7), which contributed to the positive perception and recognition of Sabaka-daikon by the demander.

3.7. Individual differences in production of anticarcinogenic ingredient, MTBITC, in Sabaka-daikon

A principal pungent compound in daikon, MTBITC, shows antimicrobial, bioantimutagenic, and anticarcinogenic effects [4–9]. Because the MTBITC level in Sabaka-daikon is 6.2-fold higher than Aokubi-daikon (the most commonly used conventional daikon in Japan), Sabaka-daikon is considered to be a superior variety than the conventional variety in terms of health benefits [7]. For the added health benefits, a fixed amount of MTBITC must be guaranteed in Sabaka-daikon. As the original Sabaka-daikon has records of cross-fertilization with two varieties, Makabe-daikon and daikon in Owari (part d and e in Fig. 4B), Sabaka-daikon of the present day sometimes shows individual differences in MTBITC production due to the unfixed genome. In this study, 19 pieces of Sabaka-daikon had 31.9% coefficient of variation (% of standard deviation/average) in MTBITC production, and a 4.2-fold difference between minimum and maximum values. In a previous analysis in 2004–2006, the coefficient of variation in MTBITC production in Sabaka-daikon was 23.1%, but that in conventional Aokubi-, heirloom Shogoin-, Karami-, and Momoyama-daikons was 9.5%, 10.9%, 6.4%, and 6.7%, respectively [7]. This indicates a challenge to obtain a race fixed in MTBITC production to guarantee added health benefits of Sabaka-daikon. As daikon in Owari is pale green-colored in root, farmers started selected-breeding to obtain foundation seeds of Sabaka-daikon by the removal of individuals having green-colored roots from the plant populations. When realizing the stably high MTBITC production fixed in Sabaka-daikon, this information would increase the customer’s desire to buy Sabaka-daikon in future. Through field interviews with administrative members, vendors, and farmers in Maizuru city, Kyoto, we explored the reasons for the success in reviving local heirloom vegetables. The primary factors were found to be passion of farmers, administrative measures, and marketing strategies of vendors. The secondary factor was the fact that one primary factor (passion of farmers) coincides on a time axis with two other factors (administrative measures and marketing strategies of vendors). We also verified that “the information regarding the health benefits of daikon contributed to motivating local

Fig. 7. Original contemporary dishes of Sabaka-daikon. (A) Fried dumpling (leaves of Sabaka-daikon and minced pork are wrapped with wheat flour skin); (B) pasta with root of Sabaka-daikon and yellowtail fish; (C) grilled chicken with root pieces of Sabaka-daikon.
residents (i.e., passion of farmers) to protect the Sabaka-daikon from extinction.” This revival of the heirloom vegetable would contribute to the availability of diverse local foods, and preserving those foods and the cooking knowledge for future generations.

Conflicts of interest

The authors declare no conflicts of interest.

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