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An overview of residential food waste recycling initiatives in Japan

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ABSTRACT

Climate change mitigation has become a focal point in governmental agendas across the world, including in Japan. As the amount of food waste produced is a big concern of Japanese authorities, this paper presents an overview of the local initiatives currently existing in Japan to foster household food waste recovery systems, highlighting their main differences and similarities in terms of system design and marketing strategy. Additionally, a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis on compost return systems, that are an endemic Japanese food recovering cycle is done. Japanese municipalities seem to always have some kind of residential food waste recycling system being advertised to their residents, being that a centralised, a decentralised, or a hybrid compost return system. Centralised segregation schemes are a rarer approach, with only few municipalities offering this type of food recycling setup. On the other hand, more than a half of the municipalities subsidises the households' purchase of a composting technology. Hybrid solutions in which consumers compost and return the final output can be a compromise solution between centralised and decentralised schemes with possible positive spillover effects in other consumers' pro-environmental behaviours.

1. Introduction

Over the past few years, climate change mitigation has become a focal point in governmental agendas across the world, including in Japan. Due to the low food self-sufficiency rate and land restrictions, the amount of food waste produced is a big concern of Japanese authorities (Liu et al., 2016). Only in 2021, approximately 5.2 million tons of food were discarded throughout the entire food system, being estimated that half of this amount came from households (MAFF, 2023, MOE, 2023c). Thus, ensuring effective methods for managing solid organic waste through collaboration among all stakeholders in the food chain, including consumers, is essential for achieving a sustainable food system.

To foster this climate action, the Japanese Ministry of the Environment (MOE) and the Ministry of Agriculture, Forestry and Fisheries (MAFF) set the goal of halving the 2000's food waste rate by 2030 (MAFF, 2019; Umeda, 2019). Alongside this goal, the increasing emphasis on promoting Circular Cities (CC) and Circular Economy (CE) programmes (Herrador et al., 2022, 2024) is closely tied to the enactment of the Food Waste Recycling Law in 2001. This law focuses on preventing food waste and establishing recycling loops, such as converting food waste into resources like animal feed or fertiliser through composting (Fujii and Kondo, 2018; Joshi and Visvanathan, 2019; Liu et al., 2016; Parry et al., 2015). A complementary law introduced in 2019 further reinforces these efforts (Okayama and Watanabe, 2024; Umeda, 2019).The latter complementary law states that to reduce household food waste, the local and central authorities are to educate businesses and consumers as well as facilitate food re-distribution projects (Umeda, 2019). CCs are cities that have policies to promote CE principles and try to enhance social well-being and economy while living in harmony with the environment (Herrador et al., 2022, 2024). Note that although some of these KPIs and directives are generally associated to edible food that is wasted (Okayama & Watanabe, 2024), this study defines food waste as food discarded regardless of being edible (e.g., leftovers), non-edible (e.g., egg shelves), avoidable or non-avoidable.

Upon these targets, legislative acts, and national government initiatives, each municipality implements them according to regional conditions, resulting in a wide range of strategies across Japan. (Hotta & Aoki-Suzuki, 2014; Inaba et al., 2022). To the authors' knowledge, there is no previous research focusing on mapping what kind of approaches Japanese organisations, communities, and local governments are using

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to enact such directives to promote food waste recycling at a household level. Moreover, Japanese food waste recycling industry has also received less attention when compared to the U.S. or the European ones. Therefore, the main goal of this work is to fulfil the latter research gap of the waste management academia. Mapping these implementation strategies is extremely important, as the wide variety of design and communication approaches has been identified as a key factor contributing to regional differences in consumers' adoption of waste prevention and reduction behaviours (Abrahamse, 2020; Dai et al., 2016; Hotta and Aoki-Suzuki, 2014; Kurisu and Bortoleto, 2011; Lee et al., 2013).

Usually, the recovery of food waste from residential areas can be a large-scale, complex centralised operation that covers a vast geographic area (centralised system), or a decentralised approach consisting of a small-scale network, or standalone processes at a community, neighbourhood, or household level (decentralised system) (Bruni et al., 2020; Pai et al., 2019). Depending on how they were designed, these systems also require different degrees of involvement of the household units. From a waste provider role (in more centralised approaches) to a stakeholder that is responsible for providing food waste, producing, and consuming the resultant compost (smaller-scale cases). Contingent on the food waste recycling process, the waste—and in some cases, sewage too—can be turned into fertiliser, animal-feed, biogas, or biomass, among other by-products (Hata, 2021; MAFF, 2021). Nevertheless, compost-based fertilisers seem to be the most common outcome of food waste recycling systems. Compost is the result of a composting process, which can be defined as the biological process where microorganisms break down organic resources.

In addition to centralised and decentralised systems, in Japan, there are also compost return systems, which can be considered a hybrid approach. In this alternative, composting happens at a residential level, but the compost can be used at a community or central level. While scholars such as Bruni et al. (2020), Pai et al. (2019), Paes et al. (2019), Rathore et al. (2022), Iacovidou and Zorpas (2022), and Kawai et al. (2020) have analysed and compared centralised and decentralised approaches, to the authors' knowledge, there is no previous academic study on such hybrid settings. Therefore, this study also contributes to academia by being the first to use SWOT analysis to explore the capabilities and liabilities of this hybrid food waste recycling system. This approach seems to be gaining traction in Japan in recent years.

In order to present a robust overview on initiatives to recycle residential food waste, this study wishes to answer three main research questions, namely: 1) What kind of promotional approaches are being used to promote centralised initiatives for residential food waste recovery; 2) What kind of promotional approaches are being used to foster decentralised kitchen food waste recycling; and finally 3) Which are the main pros and cons of hybrid systems in comparison with more widespread food waste recovery strategies.

After the literature and methodological sections, this manuscript is organised as the following: A section focusing on the marketing approaches and technical aspects of centralised food recycling systems across Japan, followed by a similar section dedicated to decentralised initiatives. Then, the SWOT of hybrid systems is presented and, finally, the main findings and limitations are discussed and summed up.

2. Material and methods

2.1. Data collection

The data on household food waste recycling initiatives across Japan was primarily collected online. Although some descriptive statistics are included in the manuscript, the analysis had a qualitative focus, aiming to identify common traits of food waste recycling systems across Japanese municipalities. This study cross-referenced information from reports and datasets about waste production, food waste initiatives, and residential waste decomposition from the Ministry of Environment of Japan (MOE) (MOE, 2023b, 2023a, 2023c, 2022, 2021), an online dataset about food waste drying machines' subsidies available by prefecture from a company that sells these machines (Island land Co. Ltd., 2023), and official websites of municipalities across Japan. In total, the websites of 152 out of the 1,718 Japanese municipalities, along with the 23 special wards of Tokyo, were inspected to understand the types of food waste recycling strategies being advocated, how these strategies are implemented, and whether any municipal reports on the initiatives were available. These cities were chosen based on previous literature, media appearances, and online searches using keywords such as: food waste collection, monetary rewards for organic food waste returns, and food waste monitoring programmes. Additionally, the selection of municipalities was complemented by cross-referencing data on subsidies for food waste drying machines available per city, as well as the location and size of the municipalities. Thus, these municipalities varied in size and were distributed across all 47 prefectures of the country.

While this paper does not cite all 152 municipalities, 51 are referenced as examples in this manuscript, such as: Aizuwakamatsu, Amakusa, Anjo, Chiba, Edogawa, Fujieda, Fukuoka, Hayama, Kakogawa, Kitakyushu, Kobe, Koshimizu, Kunitomi, Kumamoto, Minamata, Myazaki, Nagoya, Niigata, Niseko, Nishiizu, Odawara, Ogaki, Osaki, Sapporo, Satsuma, Shibata, Shimosuwa, Suwa, Toyohashi, Yamagata, Zama (Amakusa City, 2023; Anjo City, 2023a; Anjo City, 2023b; Chiba City, 2023; Edogawa City, 2022; Fujieda City, 2022; Fujieda City, 2023; Fukuoka City, 2024a; Fukuoka City, 2024b; Go Green Kobe, 2023; Hayama Town, 2023; Kakogawa City, 2024a; Kakogawa City, 2024b; Kitakyushu City, 2024; Koshimizu Town, 2024; Kumamoto City, 2024; Kunitomi Town, 2023; Miyazaki City, 2023; Nagoya City Hall, 2023; Niigata City, 2020; Niseko Town, 2024a; Niseko Town, 2024b; Odawara City, 2024; Ogaki City, 2022; Ogaki City, 2024a; Ogaki City, 2024b; Osaki Town, 2020; Sapporo City, 2024a; Sapporo City, 2024b; Satsuma Town, 2023; Satsuma Town, 2024; Shibata City, 2023; Shimosuwa Town, 2024; Suwa City, 2023; Toyohashi City, 2024; Yamagata City, 2020; Zama City, 2024).

In addition to the data gathered online, information about Kobe City's (Hyogo) composting monitoring programme was collected through in-person interviews and email exchanges with two project coordinators, as well as attendance at a citizen open workshop about the initiative. Kobe city is one of the largest cities in Japan and has since an early stage been a place focused on consumer-farmer relations, being the birthplace of the Japanese consumer co-operative movement (JCCU, 2024). Despite having now expanded to business areas such as supermarkets, the consumer co-operative movement's initial goal was to support and improve the livelihood of Kobe citizens (JCCU, 2024).

Finally, regarding the SWOT analysis of the compost collection systems, the analysis was based on pilot reports such as Kuchiba (2022), information available on the websites of participating cities, data gathered from a seminar about these systems for local citizens, an interview with a farmer involved in a compost collection project, and two interviews with members of one of the third-party companies (neither citizens nor municipalities) that coordinate and promote this type of food waste recovery approach. By interviewing different stakeholders of these programmes, a multi-dimensional perspective on the attributes of these kind of projects could be given. The emails and interviews were done in Japanese. While the SWOT analysis was also based on online information, contrary to the data on decentralised and centralised systems, the majority of the information was gathered on interviews and attended seminars.

2.2. SWOT analysis

SWOT analysis stands for Strengths, Weaknesses, Opportunities, and Threats analysis (Sammut-Bonnici & Galea, 2015; Zheng et al., 2017). This framework was used in the present study to analyse one of the food waste recycling layouts that can be found in Japan, because it is a widespread business management approach that facilitates strategic planning and discussion, that has been used as a tool to review waste

management systems by previous scholars (Paes et al., 2019; Sammut-Bonnici & Galea, 2015; Zheng et al., 2017). More precisely, this analytical tool was used to study compost returning systems as a whole (household food waste recycling process, stakeholders, transportation, the role of the households, costs) and identify their main advantages/disadvantages compared with centralised and decentralised approaches, as well as traditional methods of disposing of household food waste.

Strengths and weaknesses are internal aspects of an organisation's environment, whereas opportunities and threats are external factors (Sammut-Bonnici & Galea, 2015). Strengths and weaknesses concern aspects such as capabilities, resources, core competencies, and competitive advantages (Sammut-Bonnici & Galea, 2015). On the other hand, market opportunities and threats relate to competitors' resources, the industry environment, and the general environment (Sammut-Bonnici & Galea, 2015).

3. Food waste recycling schemes in Japan

3.1. Centralised kitchen waste recycling alternatives and incentives

In 2021, Japan summated 100 central composting facilities which were responsible for processing 0.5 % of the total waste produced in the country that year (Kawai et al., 2020; MOE, 2021, 2023b). That represents around 2 % of the total amount of waste recycled (MOE, 2021, 2023b). Not all of these facilities treat household waste, nor do all municipalities have separate collection systems for household food waste. According to another MOE report, only 212 municipalities (12.4 % of the 1,704 municipalities that answered the survey) stated to collect separately residential food waste in all their wards and 80 have a food waste segregation scheme in some areas of the city (4.7 %) (MOE, 2021). In this section, common characteristics of the centralised systems to segregate household food waste adopted by Japanese municipalities as well as the incentives they use to foster the cooperation of citizens are presented.

In Japan, characteristics of centralised food waste recycling systems vary in attributes, such as the packaging used for collection (e.g., plastic bags, paper bags, plastic bucket), collection location (e.g., kerbside or drop-off station), frequency of collection, transportation method (e.g., different truck types) (Kawai et al., 2020) and, as it was already mentioned, the final output and recycling process.

From the analysed sample, cities with larger populations tended to adopt plastic bags more often as a packing material, which in turn was associated with the use of compactor trucks (Table 1, Fig. 2 (2)). Cities which used plastic buckets for collection tended to use flatbed trucks (Fig. 2 (1)). In Ikeda town (Fukui Prefecture), the food waste is collected in paper bags and the project is run in collaboration with an Non-Profit Organisation (NPO) (Ikeda Town, 2021). Also, in Shibata city (Niigata), food waste collection is available in some areas of the city through a partnership between the city and an NPO (You&Me NPO, 2024). From the sample, only Koshimizu town in Hokkaido prefecture used a compostable bag to package the food waste, as the bag is also composted in the city's composting process. Also in the same prefecture, in Niseko town, citizens use plastic bags to segregate the waste, but then they put them in kerbside bucket stations.

Drop-off systems seem to have greater flexibility in collection frequency. However, it is relevant to mention that the drop-off bucket itself has designated collection days. In these residential segregation schemes, the role of households passes by separating food waste, so it is later collected by the cities.

As the stakeholders that provide the main input for the system, having the support and involvement of waste generators is crucial to assure that food waste recycling systems are sustainable (Iacovidou & Zorpas, 2022; Jamal et al., 2019; Kawai et al., 2020). Four main marketing strategies were found across Japan, namely: 1) reward programmes; 2) composting liaisons; 3) use cases (e.g., food labels) and 4) Knowledge sharing (e.g., explanatory videos and leaflets).

3.1.1. Reward programmes

In certain municipalities where food waste segregation was adopted, residents who participate in the programme are eligible to receive free compost. This is the case with Tsushima city (Nagasaki) and Shimosuwa town (Nagano). In Tsushima city, the possibility of receiving free compost is well visible on the project's promotional flyer and in Shimosuwa town, the compost is distributed free of charge twice a year. According to Ohashi (2008), compost availability (if it is available to the public) and price (free or not) are two of the characteristics that vary considerably from project to project.

3.1.2. Composting liaisons

Another way to promote engagement across Japan is through liaisons. Scholars have noted that liaisons can be NPOs/**Non-governmental organisations**(NGO)s, companies, leaders of community groups, women's unions, or neighbourhood associations that act as intermediaries between waste generators and central management (Dai et al., 2016; Kawai et al., 2020; Kuchiba, 2022; Kurniawan et al., 2013). This seems to be happening in Japanese municipalities too. In both Ikeda town (Fukui) and Shibata city (Niigata), food waste collection is managed by NPOs, fostering closer relationships between stakeholders and facilitating support in the separation process.

In cities such as Osaki town (Kagoshima) and Shimosuwa town (Nagano), neighbourhood leaders and women's unions inspect the content of household food waste buckets before they are transported to composting facilities. Additionally, in Shimosuwa town (Nagano), new

Table 1
Municipalities Running Food Waste Collection \Schemes.

Prefecture	City	Packing of Collection	Location	Frequency	Final output	Population*
Ibaraki	Tsuchiura	plastic bag	kerbside	designated day	compost; biogas	142,074
Aichi	Obu	plastic bag	kerbside	designated day	biogas	93,123
Kagoshima	Satsuma	plastic bag and bucket	drop-off	everyday	compost	20,243
Okayama	Maniwa	plastic bucket	drop-off	everyday	compost	42,725
Aichi	Toyohashi	plastic bag	kerbside	designated day	biogas; coal	371,920
Shizuoka	Fujieda	plastic bag	kerbside	designated day	compost	141,342
Yamagata	Nagai	plastic bag and bucket	drop-off	everyday	compost	26,543
Aomori	Towada	plastic bag and bucket	kerbside	everyday	compost; energy	60,378
Nagasaki	Tsushima	plastic bucket	drop-off	everyday	compost	28,502
Nagano	Shimosuwa	plastic bag	kerbside	designated day	compost	19,155
Hokkaido	Koshimizu	compostable bag	-	-	compost	4,623
Hokkaido	Niseko	plastic bag and bucket	drop-off	designated day	compost	5,074
Fukui	Ikeda	paper bag	drop-off	designated day	compost	9,382
Kagoshima	Osaki	plastic bucket	-	-	compost	12,385
Niigata	Shibata	-	-	collection	compost	94,927

* 2020 census

Fig. 1. (1) Plastic Bag (Tsuchiura City, 2024); (2) Plastic Bucket (Maniwa City, 2019); (3) Ikedas's Paper Bag (retrieved from Kawai et al. (2020)).

Fig. 2. (1) Compactor Truck retrieved from Tsuchiura City (2024); (2) Flatbed Truck used in Osaki.

groups of participants are required to complete a form listing all members and designating a group leader. The group leader is responsible for overseeing up to eight households, ensuring the proper storage of the group's containers, and facilitating communication between the households.

3.1.3. Use cases

Upon residential waste collection and consequent composting production, some cities (e.g., Ikeda) have created special labels for compost grown vegetables and antenna shops where these products are being sold (Fig. 3). In the case of Ikeda Town (Fukui), some antenna shops are located in other cities of the prefecture, thus promoting the relationship between cities within the same region and the consumption of local goods. Nagai city (Yamagata) has also implemented a programme in which school lunches are made with compost grown products (Kawai et al., 2020). These kinds of strategies are aligned with the ethical food consumption drivers identified in Morais et al. (2024).

There are also cities that give concrete examples of how the compost is being used or details about the recycling process's final output (e.g., Toyohashi city, Maniwa city). Moreover, despite not being free, in Yahaba town in Iwate Prefecture, the purchase of compost made from household waste is promoted directly on the waste separation calendar of the town (Morioka/Shiwa Environmental Facilities Association, 2024).

3.1.4. Knowledge and information sharing

Towada city (Aomori), Tsushima city (Nagasaki), and Nishiizu town (Shizuoka) are municipalities that are now on their project's launch/trial stage (Osaki Town SDGs Council, 2024; Towada City, 2024; Tsuruda, 2024; Tsushima City, 2024a). Thus, similarly to other cases (Bernstad, 2014; Kawai et al., 2020), collection trials were initially conducted in specific locations within the municipalities. These trials included sensitisation and promotional campaigns within the neighbourhood associations of those locations, featuring workshops and seminars. Under the "ALL COMPOST" project, Nishiizu and Tsushima city's segregation scheme and educational meetings are being developed in a city-to-city cooperation with Osaki city (Kagoshima), which already has a well-established food waste recycling system (Morita, 2017; Osaki Town SDGs Council, 2024; Tsuruda, 2024). Having access to the expertise of stablished projects can be an efficient strategy to increase the success rate of new interventions (Kurniawan et al., 2013).

In addition to this knowledge-sharing factor, another point to be

Fig. 3. (1) Ikeda City Antenna Shop (Ikeda Town, 2015); (2) Ikeda's Compost Label (Ikeda Town Agricultural Corporation, 2024).

highlighted is the use of English words in the advertising of the latter initiative. In this case, the project is called "ALL COMPOST" and Tsushima's promotional flyer used as cover words "A LITLE EFFORT" (Fig. 4). According to Leung & Chan (2016) and Holmquist & Cudmore (2013), the use of English words by non-English speaking countries in marketing campaigns can increase the appeal of the product/service that is being advertised. These are short and easy words that target two composting drivers: the unity and collective aspect of Japanese culture, and the composting required effort (often seen as a barrier), respectively. Additionally, in Towada city (Aomori), a Q&A document was created based on the most common questions from the seminars and after the feedback given by households that participated in a food recycling experiment. The latter highlights the importance of collecting and taking into consideration the feedback from waste generators.

Many cities also include in their messaging illustrative figures, waste flow charts, visual cues of the food waste segregation rules, examples of which kind of collection container (bag, bucket) should be used, and/or the main advantages of the system (Fig. 4). Tsuchiura city, for example, also has on their website an explanatory video on how to properly segregate the food waste (Tsuchiura City, 2024).

The messaging style seems to differ depending on the stage of implementation of the project. For instance, in Yahaba town (Iwate), the food waste separation process was simplified and included into the town's waste collection calendar. In Nagai city (Yamagata) and Kunitomi town (Miyazaki), which started their programmes in 1997 and 1985 respectively (Ohashi, 2008), information regarding food waste segregation passes by telling the residents on which day of the week this type of waste is collected. Although in these cities' food waste collection is most likely part of people's routines, Kawai (2019) has called for the importance of ensuring that new residents are aware of how to properly segregate the food waste.

3.2. Decentralised household composting incentives in Japan

This section focuses on the characteristics and promotion strategies of decentralised food waste recycling systems, which are an alternative to centralised collection of food waste. In these systems, the food waste recycling happens at the household or community levels, implying a higher-level involvement of households in the treatment of their organic residues.

There are a variety of household food waste recycling alternatives that can be incentivised by local entities. At a decentralised scale, these initiatives often rely in some kind of composting process. In Japan, the most frequently advertised technologies appear to be EM bokashi composters, electric drying machines and composters, cardboard box composters, manual gallon/bucket composters, and Japanese alternative manual technologies such as Kiero composters and composting bags.

Decentralised alternatives can be incentivised in parallel with centralised food collection systems. In fact, they can be an important complement to centralised schemes (Pai et al., 2019). In Japan, Fujieda in Shizuoka Prefecture offers monetary assistance for the purchase of electric composters even though it has a food waste segregation scheme. However, financial assistance is not the only possible promotional strategy. The authors identified information sharing, monitoring and trial programmes as well as reward programmes as strategies adopted by the local governments.

3.2.1. Monetary incentives and information sharing (seminars, leaflets, videos)

The most common incentive to household composting adoption in Japan is financial assistance. Approximately 56 % of the municipalities offer financial support for the purchase of at least one composting technology (food waste dryers or electric food waste composters). Although the authors did not have the means to verify all 1,718 municipalities and 23 special wards of Tokyo, it seemed that many cities offering financial support for the acquisition of electric composting technologies also provided financing for EM bokashi composters and composting gallons/buckets. Among the 47 prefectures, more than 85 % of the municipalities in Tochigi, Mie, Ishikawa, and Nagano offer financial assistance. On the other hand, in Aomori, Fukui, and Hokkaido less than 20 % of the municipalities offer these monetary incentives.

In addition to the type of technology financed, other application conditions vary across municipalities (Table 2). For example, the covered percentage can range from 25 % on electric composters in Aizuwakamatsu (Fukushima) and Marumori (Miyagi), to almost a full refund of the purchase value in places like Ayase (Kanagawa) and Daisen (Tottori). In some cities, the percentage covered varies depending on the type of technology. As the electric machines have a higher cost than other technologies (e.g., EM Bokashi, gallons, buckets), some cities cover a higher percentage of the latter. Moreover, in Hamamatsu (Shizuoka), designated types of composting buckets can be obtained free of charge (Hamamatsu City Hall, 2023). Regardless of the percentage that is covered by the financial assistance, municipalities always set a ceiling value to the support that can be given.

While the majority of programmes target all citizens, some municipalities have small nuances depending on if a person lives in the suburb or in the central area of the town (Table 2). Overall, the programmes work in a first come first served system until the yearly budget is

Table 2
Financial Assistance Conditions.

Application Parameter	Conditions
Technology Type	Electric; Manual; EM Bokashi; and Cardboard Box.
Equipment Type	Some cities/towns provide a specific list of the models that are covered by the monetary programmes.
Tax	Included or not in the covered cost.
Eligible People	All residents; city centre; suburbs.
Participation Type	Fixed amount; Percentage of the equipment cost.
Participation Value	Participation percentage/amount changes across cities.
Application Timming	Before or after the purchase of the equipment; Designated application window.
Price celling	Maximum value that is covered by programmes.
Application Requirements	Previous participation; Yearly allocated budget.
Purchase Place	Designated place of purchase or not.

Fig. 4. (1) Satsuma's Household Food Waste Flow (Satsuma Town, 2023, 2024); (2)Tsushima's Flyer (Tsushima City, 2024a, 2024b); (3) Maniwa's Food Waste Separation Rules (Maniwa City, 2019).

achieved. Usually, a household has a limit on the number of times and number of pieces of equipment that can apply for.

3.2.2. Knowledge and information sharing

In order to make available the information about subsidies' conditions to communities, cities have to have at least one communication channel. This channel is often the cities' websites. In addition to such information, local governments provide information on the pros and cons of each process/equipment, on how to make the compost, or previous users' feedback (e.g., Hayama town in Kanagawa and Ogaki city in Gifu). Having such information can foster long-term engagement in composting and help new users to evaluate which technology better suits their lifestyle. However, the detail and way this information is passed down to the citizens changes deeply across local governments. In some cases, it seemed that the information was made available primarily to people who had prior interest in engaging in the behaviour, rather than with the goal of attracting new adopters.

Thus, more than making available or not such monetary incentives, having direct and personal contact via workshops, seminars, using social media, local media (like journals) or didactic content to share knowledge may raise the engagement in composting. In fact, cities like Edogawa (Tokyo) have opted just for providing resources and educational seminars rather than funding the purchase of equipment. As thereason for the decision, the city mentioned the high dropout rate of household composting. Cities such as Sapporo (Hokkaido), Fukuoka (Fukuoka), Sendai (Tohoku), Odawara (Kanagawa), and Gifu (Gifu) also provide courses on composting and ways of using the compost in a home gardening regularly. In the case of Fukuoka city (Fukuoka), these training sessions are run by a NPO (Fukuoka City, 2024a).

Moreover, in Nagoya city (Aichi), the financing happens at the association/group level and not at the household level. In other words, to foster decentralised community level composting, neighbourhood associations and environmental groups are eligible to receive monetary assistance if they intend to tackle food loss and food waste recycling issues.

3.2.3. Monitoring programmes

One alternative/complementary option to monetary incentives is monitoring programmes. Monitoring programmes differ from seminars and workshops as instead of happening in a single point in time, the monitoring happens throughout a certain period of time (e.g., 3 months). Under this promotional format, cities open application windows and once the vacancies are full, they distribute, sometimes free of charge, the necessary composting equipment to the participants. Following this, over a determined period of time, participants are expected to track progress and complete a feedback survey at the end of the designated period.

These programmes are often associated with a specific type of composting technology. To the authors' investigation, from 61 monitoring programmes, some had cardboard box composting (e.g., Kakogawa city in Hyogo) or composting bags (e.g., Amakusa city in Kumamoto) as the base technology. However, the most commonly examined equipment was electric machines (e.g., Suwa city in Nagano) and, in partnership with the Kiero NPO (Kiero Official, 2024), the Kiero composting method (e.g., Kobe city in Hyogo and Chiba city in Chiba). More than a half of the 61 programs analysed used the latter method. Some cities also ran monitoring programmes in more than one composting process (e.g., Myazaki city in Myazaki).

The "Kiero" method is a Japanese composting alternative that has been a focal part in food waste recycling in Zero-Waste towns like Kamikatsu and Minamata (Jakimiuk et al., 2023). It uses only natural soil as a base material and requires less mixing and overall maintenance than other techniques (Jakimiuk et al., 2023). Once it is supported by an NPO, in addition to local government support, there is also the opportunity to build a community among people who have adopted this technology through the NPO. For example, in the summer of 2023, a season that in Japan is associated with festivals, the Kiero NPO promoted an online "festival" in which people, regardless of their location, were invited to share their stories and experiences with the "Kiero" method (Kiero Official, 2023).

Also, in the summer of 2023, Kobe city (Hyogo) launched a Kiero monitoring programme for adults and, as part of children's summer school projects, for children as well. (Fig. 6). Since the summer, a second application window opened for adults around the winter holiday season. Similarly to Kiero's online festival, the city embedded the project within the Japanese cultural landscape by using the Summer Research School projects of elementary schools as an engagement vehicle. As shown in Fig. 5, the messaging of each booklet was targeted to the specific audience (parents/adults and children). Information meant for the younger participants had simpler explanations and used words such as "challenge" and "hint" passing the idea of gamification of the composting process (Fig. 5 (2)). Additionally, the composting tasks on the children's book often included the picture of a child.

According to staff members, the project took a year to prepare, and it was advertised through social media platforms such as Facebook, Line, and Instagram. It was also advertised on local newspapers, in adds inside trains, and in schools. Promotional events and workshops were also held in more than one occasion during summer. The monitoring workshops covered information about the Kiero composting method (its origin, how it works, how it is made, and how to use it), as well as an introduction to Kobe city's waste reduction goals. Feedback surveys were given to participants, approximately one month and three months after the start. Following the monitoring period, the organisation members highlighted that more important than tracking participants' future engagement, they wished to encourage people to continue by posting the results of their efforts on the programme's official website.

Among the most commonly asked questions at monitoring workshops, the Kobe Kiero organisers mentioned aspects such as decomposition time, the type and amount of food waste that can be put in the composters, how frequently waste can be added, how to use the final output, what to do in case of insect infestation, and how to increase the speed of the decomposition process.

3.2.4. Trial programmes

Prior to the purchase of a composting technology, some cities give the citizens the possibility of having a trial period in which the city council lands a composter to the interested household. The price of the composting equipment can vary deeply depending on its features. In particular, electric/automatic composters or waste drying machines, can be quite costly. Therefore, municipalities like Komatsu city (Ishikawa) have a trial programme (Komatsu City, 2024). Trial programmes can vary in length, with some places offering a rental for up to 3 months.

3.2.5. Reward programmes

In cities such as Odawara (Kanagawa), Anjo (Aichi), and Sapporo (Hokkaido) the use of electric composters, drying machines or composters is not incentivised exclusively by monetary assistance on the purchase of the equipment but also through rewards given to citizens that return the dried food waste/compost surplus. In Odawara city (Kanagawa), people that want to start composting are eligible to receive cherry tomatoes. In Anjo city (Aichi) citizens are eligible to receive paper bags, toilet paper, tissue boxes, or garbage bags (for other waste categories) in turn of dried food waste. These cities choose as their rewards programmes essential goods in one's daily life, such as toilet paper.

Similarly, in Sapporo city (Hokkaido) and Yamagata city (Yamagata), people who return their dried waste/compost are eligible to receive vegetables (in Sapporo a regional type of onion is being given). Moreover, in Niigata city (Niigata), people can receive the resultant compost free of charge (as happens in some cities, which collect household food waste separately), and in Sendai city (Miyagi) and Ogaki city (Gifu), consumers can accumulate points to later exchange them not

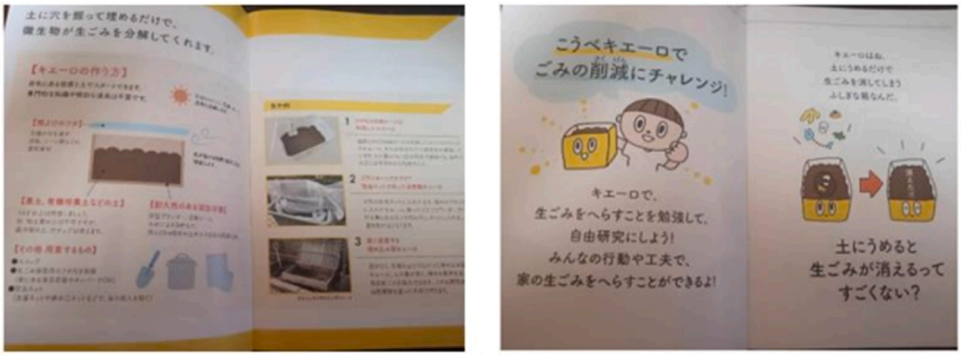

Fig. 5. (1) Kobe's Kiero Monitoring Programme Guidelines for Adults; (2) Kobe's Kiero Monitoring Programme Guidelines for Children.

Fig. 6. Waste Mascot Merchandise of Sendai (Sendai City, 2024b).

only for garbage bags, vegetables, or compost but also chopsticks and other kinds of merchandise with the city's waste management mascot (Fig. 6). Kitakyushu city (Fukuoka) and Kakogawa city (Hyogo) have point systems that can be later used, for instance, on commuting cards (IC cards). In cities where people can collect points, in addition to composting related activities, residents can often win them by participating in several environmental initiatives aligned with Sustainable Development Goals (SDGs).

These rewards programmes are based on a food waste recycling setup that appears to be increasing in popularity in Japan. However, to the authors' knowledge, there are no international studies on it. Under this setup, composting is done at the household level, but it is not necessarily used by the consumers themselves. Instead, it can be partially or fully returned to farmers, community associations, community farms, or recycling centres. The next section will further explore the flow of this alternative system.

3.3. *A point in between. Composting collection systems. A SWOT analysis*

In Japan, a hybrid solution between large-scale (centralised) and small-scale (decentralised) approaches can be found. Under this hybrid solution, the responsibility for the composting process (or, in some cases, the food drying process) lies with the households, but the output from the process can be used by local gardens, farmers, or a secondary treatment facility. This means that the recycling of organic waste is done on a decentralised level, but it can then either be gathered for larger-scale applications or, if the households choose to do so, be used by themselves (Fig. 7). Contrary to a centralised system in which the residential organic waste is segregated to be treated in a facility to generate energy or fertiliser, in decentralised and hybrid systems the residencial organic waste is processed by the citizens (Fig. 7). While in a

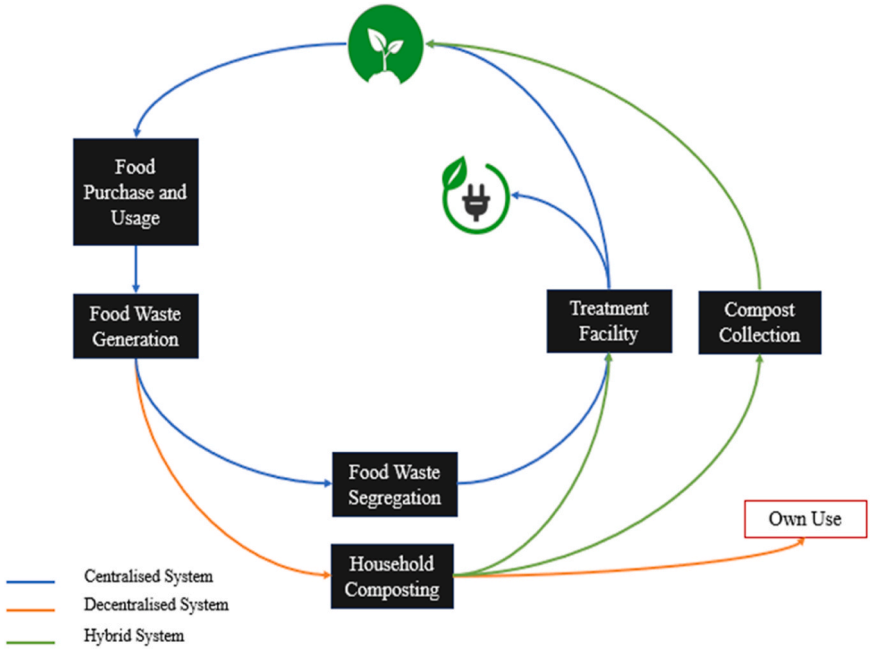

Fig. 7. Possible Flow of Food and Food Waste involving Households in Japan.

decentralised scheme the output is used by the recycling unit, in a hybrid solution, citizens can return their output material to a facility, where it is then processed, or directly to food growers (Fig. 7). Note that, even though this manuscript focuses on residential food waste, this alternative could possibly be adapted to wholesalers or food producers.

In addition to the cities mentioned in the previous section, which run these kinds of return systems alongside reward programmes, Kumamoto city (Kumamoto), Fukuoka city (Fukuoka), Gifu city (Gifu), and Zama city (Kanagawa) also have compost/dried waste return programmes. Moreover, a one yearlong pilot project on this hybrid layout was run in Kawasaki city (Kanagawa) during 2021/2022 (Kuchiba, 2022). As a mixed solution, these systems have the benefits of both centralised and decentralised systems. Consequently, they also share negative points with both setups. To better understand the liabilities and benefits of this business model, the authors used the SWOT framework. The SWOT covers aspects as the social, economic, geographical, and environmental characteristics of this alternative treatment of household organic waste.

3.3.1. Strengths

Firstly, in comparison to a traditional food waste disposal scheme, and similarly to other food waste recycling processes, hybrid layouts contribute to a reduction in the food waste that is incinerated or ends up in landfills.

The second strength of this business model is related to its lower initial and running costs compared to centralised alternatives. Despite having associated transportation costs, they do not necessarily require a central treatment facility, as the composting process is done by the consumers/households. Since having a treatment facility is not a necessary condition for these setups, their implementation period can also be faster than a purely centralised alternative. Additionally, according to Bruni et al. (2020), the more central a system is, the higher the possibility of the contamination. In a hybrid system, given that households can also be users of the produced compost the contamination level is expected to be smaller than in centralised layouts.

When compared to decentralised household systems, hybrid schemes can better optimise the use of compost resources. According to a member of one of the composting bag companies, people tend to use the entire first batch of compost and return the second one, or use part of the produced batch and return the surplus amount. At the same time, the collected compost usually already has a designated destination. For instance, in Gifu city, the compost is used in school gardens and the students are involved in applying the compost to the gardens. The compost can also be used in community gardens or directly returned to farmers (Kuchiba, 2022). When managed by or in partnership with a company/NPO, it can also link farmers beyond a specific city's boundaries, thus offering more geographical flexibility than other systems.

Moreover, these hybrid programmes tend to target composting technologies customised to be kept in small spaces, which is not necessarily the case with mainstream household composting technologies. This is the case with electric composters, composting bags (Fig. 8), or even cardboard box composting (as seen in Gifu city, Gifu). In particular, composting bags are a mobile and energy-free solution, which is made domestically from recycled materials (Chikyu-Labo, 2024; LFC, 2024).

3.3.2. Weaknesses

Despite not having as many associated costs as a centralised composting process, hybrid systems still have transportation costs, which do not occur at the household composting level. They also demand greater efforts from the household unit, when compared with segregation schemes or traditional disposal. As the responsible party for the food waste recycling, the citizens need to acquire a composting technology, learn about the process, and control it. It also implies higher costs for citizens (e.g., acquisition costs, electricity, dirt, composting materials).

Another weakness of the system is the inaccurate composition of the output material—the compost. According to a farmer who has been participating in a household compost return system for the past 2 years, the composition of organic waste can change depending on the household, making it difficult to know the exact composition of each compost batch. Additionally, the received compost requires an additional maturation period when it reaches the farming plot, which necessitates a storage place. In comparison with traditional fertilisers, its application in the field is also a more time-intensive activity, said the farmer.

3.3.3. Opportunities

Especially in Japan, where many houses in metropolitan areas are small in size, having a technology that fits into the routine and life in smaller spaces can attract people who are environmentally concerned but do not have a backyard or gardening interest. This is the case with composting technologies often associated with compost return schemes.

Another opportunity of hybrid systems relates to the distribution channels they offer. Depending on who is operating the collection system, opportunities for cooperation between NPOs, companies, farmers' associations, local government, and communities may arise. It can also provide an opportunity to integrate composting systems with ICT technologies, such as apps (Kuchiba, 2022). Additionally, it can foster Farm-to-Fork direct links, between households that produce and return the homemade compost and farmers who used it to organically grow fruits and vegetables.

Similar to other food waste recycling systems, there is the possibility of spillover effects on the purchase of organic products, gardening, and awareness of the amount of waste produced, leading to a decrease in food waste. For example, as previously mentioned, in Gifu, compost is used as an educational resource in schools (Gifu City, 2024). Cities, as well as composting technology companies, also often offer gardening workshops on how to use the compost. These in-person events are opportunities to create descriptive and social norms and build human connections that can further foster the shift to these behaviours.

Finally, as mentioned by a farmer using household compost, due to the recent steep increase in the prices of chemical fertilisers, household composting can alleviate the economic pressures farmers face, as well as increase their selling channels. Thus, the increasing costs of "traditional" farming can lead to the adoption, or at least the trial, of these hybrid systems by farmers.

Fig. 8. Different Models of Composting Bags and an Example of an Electric Composter (retrieved from Chikyu-Labo (2024), Ibuki Farm (2024), Komatsu City (2024), LFC (2024)).

3.3.4. Threats

As households have the responsibility of making the compost, one of the main threats concerns the low engagement of the public. According to a composting bag staff member, some people drop out due to lifestyle changes, relocating to a different city, or because they failed at making compost. Similarly to other decentralised systems, a big challenge is understanding effective ways to attract new adopters and maintain the long-term engagement and motivation of current participants.

Regarding the output material, as there is no clear idea of the constitution of the compost received from households, farmers who are part of these programmes are not eligible for the Japanese certification for organic products (JAS), said a participating farmer. Moreover, this uncertainty about the components can make it more difficult for farmers who are more risk-averse to engage, he added.

Another concern is the scalability of these programmes and the unstable supply and demand of the compost. Before applying compost made from kitchen food waste, it is usually necessary to have a final maturation step. This requires time, space, and manual labour, which a participating farmer mentioned as barriers to expanding the use of this type of fertiliser. Moreover, since household composting is more susceptible to drop-out cases and the amount of compost depends on the number of consumers/businesses returning it, the expansion of these schemes may proceed at a slower pace than that of "traditional" fertiliser. The need to have a compost receiver (farmer, garden, or other) also contributes to this issue. Additionally, while high prices for chemical fertilisers present an opportunity for household composting, if the current market trend reverses, farmers will have fewer incentives to use this type of fertiliser.

4. Discussion

4.1. Study implications

The current paper identifies the main characteristics and promotional approaches of Japanese centralised and decentralised residential food waste recycling systems as well as the main strengths, weaknesses, opportunities, and threats of compost return systems, a household food waste recycling solution that can be found in Japan. No food waste recycling approach is free of drawbacks, so it is important, prior to implementation, to assess the social, economic, geographical, and environmental conditions of the target location(s).

Especially in centralised systems, which are costly, large-scale investments, it is crucial to assess whether the necessary conditions regarding the project's social context, cooperation and understanding of residents, institutional aspects, governance capability, financial aspects, and technical aspects are met (Kawai et al., 2020). Accordingly, in Japan, municipalities of different sizes seemed to adopt different operational systems. Despite running costs and issues with source contamination and consequent quality of the recycling process output (Bruni et al., 2020), food segregation schemes can produce not only soil amendments but also energy and demand less from the citizens (they only need to separate the food waste and not process it).

Regarding household or community composting schemes, they can have benefits at logistical, ecological, economic, and social levels (Pai et al., 2019). Compared with centralised alternatives, they have lower transportation and treatment costs, fewer contamination issues, and can stimulate local entrepreneurship and community spirit (Bruni et al., 2020; Pai et al., 2019). Decentralised approaches seem to be the most commonly promoted in Japan. Nonetheless, as mentioned by Pai et al. (2019) and seen in papers such as Kurisu & Bortoleto (2011) and Morais & Ishida (2024), these systems tend to have low engagement rates. To promote adoption, Japanese local governments rely mostly on: 1) financial assistance; 2) knowledge and information sharing 3) monitoring programmes; 4) trial programmes; and 5) reward programmes.

While subsidies were the most widespread promotional approach, some of the prefectures across Japan barely had municipalities offering them. In the U.S., Niles (2020) noticed that many people in rural areas were already composting in their backyard. Given Aomori, Fukui, and Hokkaido prefectures have many rural areas within their boundaries, a similar situation might be occurring. If that is the case, offering subsidies to purchase composting equipment might be redundant. Another reason may be that some municipalities on these prefectures have adopted centralised approaches. However, further research is needed to understand such financing nuances.

Trial programmes, especially for expensive composting technologies, allow households to make a more robust choice, save money, and prevent additional waste from units that could be discarded in a dropout situation. In other words, it decreases the chances of a premature dropout. Moreover, monitoring programmes can foment community spirit, knowledge sharing, and increase the motivation of individuals to continue composting. They can also act as a show case for future adopters. According to civic scientists, sharing such stories, feedback, and ideas with fellow participants and local communities on social media can help catalyse a project's development and expansion (Krug et al., 2022; The Land Institute, 2024).

These strategies are not only aligned with the methods for disseminating information mentioned by Dai et al. (2016) and top-down and bottom-up decentralised initiatives suggested by Pai et al. (2019), but also share some similarities with promotional strategies of centralised schemes highlighted both in this study and by international scholars (Bernstad, 2014; Dai et al., 2016; Evison and Read, 2001; Jamal et al., 2019; Kawai et al., 2020; Kawai & Huong, 2017; Moh and Abd Manaf, 2014; Niles, 2020; Sussman & Gifford, 2013; Widyatmika & Bolia, 2023). This paper identifies four main promotional strategies for centralised systems: 1) reward programmes; 2) liaisons; 3) use cases of the final output of the process; and 4) knowledge and information sharing.

Liaisons can encourage residents to participate in separation at the source, as well as ensure the proper disposal of the organic waste (Kawai et al., 2020). Furthermore, based on previous research, these personal interactions can facilitate the adoption of pro-environmental behaviours by making social norms more prominent and building group identity (Abrahamse & Steg, 2013; Dai et al., 2016; Postmes et al., 2005). These mediators can also facilitate direct links between waste generators and farmers. Liaisons can be NPOs, government officers, or even members of the community. Similarly, showing citizens the possibilities that can arise from their actions and giving concrete examples in which compost is being used, can not only promote the segregation of waste but also foster the consumption of ethical food (Kawai et al., 2020).

As for hybrid systems, they seem to heavily rely on reward programmes, Farm-to-Fork links, and knowledge sharing as promotional strategies. The strengths of this business model are its low initial and running costs, the optimisation of output resource use, geographic flexibility, the reduction of greenhouse gas emissions, and the use of small-space composting technologies.

In terms of weaknesses and threats, compost-returning systems require constant monitoring and support, rely heavily on consumers, and involve transportation and storage costs. Despite providing farmers with a good alternative to expensive chemical fertilisers and fostering collaboration between multiple stakeholders— promoting Farm-to-Fork links and positive spillover effects on consumer behaviour—these systems are also challenging to scale, may face issues in maintaining consistent quality, and can struggle with balancing supply and demand.

Given recent central government directives and the interconnected nature of reduce, reuse, and recycle, some cities try to bundle these concepts and promote more sustainable lifestyles as a whole, instead of focusing on a single behaviour. This is the case for cities like Kobe city (Hyogo) or Sendai city (Miyagi) which have separate social media for their environmental initiatives and organise events such as city cleaning days or provide eco-friendly recipes (Kobe city, 2024; Sendai City, 2024a). These initiatives can foster the connection of citizens with both nature and their local community. In some cities, point-collecting reward systems cover several SDGs. This gamification as an incentive

can be especially attractive to younger generations. Many cities also have specific mascots for their environmental waste reduction initiatives. Although this paper did not directly target community actions, they also play a role in the promotion of sustainable lifestyles and food waste recycling.

In Osaki town (Kagoshima) and Kamikatsu town (Tokushima), this eco-friendly facet became a trademark of the towns, attracting eco-tourism and national and international partnerships with cities that wish to adopt eco-friendly measures. Additionally, Japan is currently facing depopulation of rural areas and population shrinkage (Kawai et al., 2022; Koizumi, 2022), so food waste recycling alternatives developed by municipalities should take this into consideration as well.

4.2. Limitations future work

One of the limitations of this study is its data. Ideally, the number of interviews would be larger, and more types of stakeholders would have been interviewed. Moreover, even though this study intends to provide an overall perspective on the initiatives to foster the recycling of residential food waste, not all the municipalities were thoroughly examined. This analysis was also mostly qualitative, and further research should try to explore these initiatives from a quantitative perspective.

While this work presented existing composting layouts and their promotional vehicles across Japan, it did not analyse which vehicle or type of messaging had the highest market penetration, nor did it check if this message should be adjusted depending on consumer profiles. Additionally, given that the number of cities collecting feedback about monetary subsidies and composting experiences seems to be increasing, identifying the similarities and differences across the different cities' feedback can also be helpful to design or restructure Japanese food recycling systems.

5. Conclusions

Japanese municipalities appear to always have some type of food waste recycling strategy being advertised to their residents, whether it is a centralised, a decentralised, or a hybrid system. Centralised segregation schemes are rarer, with only around 17 % of municipalities offering this type of food waste recycling setup, while the most common approach is the promotion of decentralised food waste recycling at a community or household level. While some cities only provide suggestions on how to engage in food waste recycling, more than half of the municipalities subsidise the purchase of a composting technology.

The way information about food waste recycling alternatives is communicated to the citizens, the characteristics of the system, and the number of promotional vehicles used by local governments, varies greatly across the country. Hybrid solutions, in which consumers compost and return the final output can be a compromise solution between centralised and decentralised schemes with possible positive spillover effects in consumers' pro-environmental behaviours. The latter setup seems to be a unique to Japan.

Despite cities promoting food recycling at different scales, some marketing strategies were common across schemes, including the use of food labels and food markets as promotional vehicles; community liaisons; messaging using English words; videos and explanatory images; workshops; visits; the use of social media and local newspapers as promotional tools; and, finally, the availability of helplines via LINE or other social media. To increase the circularity of consumed resources and create robust recycling networks, collaboration and involvement of several stakeholders within the food system (companies, NPOs, farmers and neighbourhood associations, local governments, producers, and consumers) should occur more frequently. When developing and designing food waste recycling systems, considering the geographic specificity of the location is also essential.

CRediT authorship contribution statement

Morais Ana Catarina: Writing – original draft, Software, Methodology, Investigation, Data curation, Conceptualization. **Ishida Akira:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors declare AI-assisted technologies were only used to improve readability and language.

Declaration of Competing Interest

The authors declare no competing interests.

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Data availability

Data will be made available on request.

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