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EDITED BY
Tapan Kumar Nath,
University of Nottingham Malaysia Campus, Malaysia

REVIEWED BY
Jung-Sun Gloria Kim,
Seoul National University, Republic of Korea
Luca Lombardo,
Council for Agricultural Research and Economics, Italy

*CORRESPONDENCE
Hongjun Yu
yuhongjun@caas.cn
Jingyong Jiang
jjy5971@163.com

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Home food gardening in modern cities: advances, issues, and future perspectives

Jingcheng Xu[1,2], Tingwei Lin[2], Ying Wang[2], Weijie Jiang[1], Qiang Li[1], Tao Lu[1], Yahui Xiang[3], Jingyong Jiang[2]* and Hongjun Yu[1]*

[1]State Key Laboratory of Vegetable Bio-breeding, Institute of Vegetables and Flowers, Chinese Academy of Agricultural Sciences, Beijing, China, [2]Taizhou Academy of Agricultural Sciences, Taizhou, China, [3]Taizhou Urban and Rural Planning Design Institute Co. Ltd., Taizhou, China

Against the backdrop of the unexpected COVID-19 epidemic, governments are facing significant challenges in mobilizing food resources, particularly fresh products. It is inevitable that there will be intermittent shortages of food during the pandemic. As a result, home food gardening has gained considerable attention from city residents and policymakers in modern cities. This is due to its potential to provide food during humanitarian emergencies and lockdown. Moreover, home food gardening is increasingly becoming a popular recreational activity in many countries, offering therapeutic benefits such as fostering social bonds through knowledge-sharing and fruit-sharing, improving mental and psychological well-being, promoting outdoor physical exercise, and strengthening the connection between humans and nature. This review provides a comprehensive summary of the latest advancements in home food gardening, including cultivated species, devices, technologies, and current issues. It also proposes perspectives based on current researches to serve as a reference for future research and development.

KEYWORDS

home food gardening, urban agriculture, self-provisioning, COVID-19, horticulture

1 Introduction

The 21st century is characterized by rapid urbanization (Lal, 2020). While urban development brings benefits, it also poses certain challenges. At present, agricultural production ability is becoming increasingly vulnerable due to diminishing availability of productive land in a majority of highly urbanized regions in China over the past two to three decades (Li et al., 2023). It is projected that by 2030, two-thirds of the world's population (about 5 billion people) will be living in urban areas, and this proportion is expected to increase to approximately 68% (about 6.7 billion people) by 2050 (Lal, 2020; Richardson and Arlotta, 2022). Fresh products, which refer to unprocessed or minimally processed fruits and vegetables, play a crucial role in human diets as they are rich in dietary fibers, essential minerals, and vitamins (Romero et al., 2022; Zhang et al., 2023). With the ongoing urbanization and unprecedented demographic pressure in cities, the availability of fresh products in urban areas heavily relies on peri-urban and adjacent rural areas, as well as external supply chains. This trend is observed globally (Zasada et al., 2019; Diehl et al., 2020; Dorr et al., 2023; Li et al., 2023).

Home food gardening (HFG), also known as residential food gardening or household food gardening, involves creating small-scale farms and growing edible or medicinal plants with some decorative value in private residential backyards, front yards, balconies, kitchen windowsills, bay windows, patios, terraces, rooftops, and other marginal lands next to a dwellings. Actually, HFG is a kind of small-scale farming implemented within the urban areas or rural areas, and its products are mainly used for self-consumption rather than for profit. Additionally, there is a cross relationship between HFG and indoor farming, because HFG can be carried out indoors (e.g., kitchen windowsills, and bay windows) or in open spaces (e.g., backyards, and rooftops) (Ghosh, 2014; Degefa et al., 2021; Mullins et al., 2021; Hong and Zimmerer, 2022; Richardson and Arlotta, 2022; Baliki et al., 2023; Cruz et al., 2023; Ma et al., 2023; Ezzeddin et al., 2024).

In the early colonial periods of the New World, carrying out HFG to supply the home diet was a requisite of life for most colonizers (Burgin, 2015). Even today, in developing countries like Bangladesh, Cambodia, Indonesia, Rwanda, Sri Lanka, and Tanzania, the availability of daily food *per capita* is below international health standards, HFG is still of great necessity (Thamilini et al., 2019; Baliki et al., 2022; Depenbusch et al., 2022; Ichinose et al., 2023; Issahaku et al., 2023; Suwardi et al., 2023).

Against the background of global city densification as well as geopolitical tensions currently, HFG has the latent capacity to be an effectual nature-based solution for mitigating food security issues (Lal, 2020; Li et al., 2023).

The COVID-19 pandemic is one global public health emergency that poses mass hospitalization and the death of countless people (Marques et al., 2021; Wu et al., 2022). Since the outbreak of COVID-19, in an attempt to effectively suppress the dissemination of the highly contagious coronavirus, on a global scale, most governments have implemented strict epidemic prevention policies, for instance, imposing longstanding mobility restrictions and social distancing measures (Erokhin and Gao, 2020; Laborde et al., 2020; Basu et al., 2021; Cerda et al., 2022; Godrich et al., 2022; Turnšek et al., 2022). However, these containment countermeasures have had a significant impact on the social life of citizens, causing a great deal of discomfort. Furthermore, they have exposed the fragility of food supply chains and highlighted the shortcomings of long food mileage in urban and urbanizing areas, thereby profoundly derailing civic sustenance availability worldwide (Erokhin and Gao, 2020; Laborde et al., 2020; Basu et al., 2021; Cerda et al., 2022; Godrich et al., 2022; Turnšek et al., 2022). Especially in populous cities, the availability of fresh and nutritious vegetables has become a major concern for urban inhabitants, especially those belonging to marginalized and mid- to low-income populations (Theodorou et al., 2021; Baliki et al., 2023; Ma et al., 2023). The precarious or totally disrupted food supply chains caused huge panic among urban denizens, stimulating them to empty municipal grocery stores or supermarket shelves in proximity (Cattivelli, 2022). Consequently, fresh food supplies frequently fell short of meeting local demands, which in turn led to triggering price boom and worsened the challenges of unequal access and distribution of fresh products among vulnerable groups amid the strain of the COVID-19 pandemic (Cattivelli, 2022).

The unexpected epidemic brought HFG to the public's attention (Music et al., 2022). Numerous urban residents and policymakers are deeply aware of the significance and necessity of self-sufficiency of inexpensive sources of high quality and nutritious produce in closed urban residential areas for emergencies (Aditya and Zakiah, 2022; Cattivelli, 2022; Turnšek et al., 2022; Baliki et al., 2023; Perez-Lugones et al., 2023). Within this crisis, peoples' interest and participation in HFG that is lack of focus prior to the COVID-19 pandemic has substantially enhanced, making HFG are becoming trendy on residential compounds and apartment blocks in many countries or territories like China, American, Indonesia, Canada, Slovenia, Norway, Estonia, Switzerland, Iceland and others (Mullins et al., 2021; Aditya and Zakiah, 2022; Kim et al., 2022; Music et al., 2022; Turnšek et al., 2022; Ma et al., 2023; Perez-Lugones et al., 2023). A survey showed that 17.4% of respondents in Canada and the United States started carrying out HFG in 2020 during COVID-19 pandemic (Mullins et al., 2021). Another study in Europe revealed that an approximately 10% increase in HFG during COVID-19 pandemic in the sample population (Turnšek et al., 2022). As a result, there has been an exponential increase (in some cases up to 450%) in the demand for gardening products related to HFG, including seeds, pots, trowels, pruning shears, trellis, yellow sticky traps, sprinklers, garden gloves, fertilizers, and substrates (Mullins et al., 2021). Additionally, sales of handbooks on this subject have also seen a significant boost (Mullins et al., 2021). Notably, a significant portion of these escalating orders came from novices on gardening, interestingly, mainly Millennials, while the remaining portion has been from growers with revival in interest in HFG (Mullins et al., 2021).

In actuality, HFG effectively reduces "food miles", decreases the demand for logistics processes, conserves more fossil fuels, lowers transportation emissions, minimizes perishable food losses during transportation, contributes to a partial improvement of food sovereignty, and tackles starvation and malnutrition caused by delays in long-distance fresh products transportation owing to a pandemic and other forms of traffic congestion or major disruption (Richardson and Arlotta, 2022; Li et al., 2023; Ma et al., 2023).

In addition to serving as a means of self-provisioning food during initial pandemic-related home confinement or other similar special periods (such as wars and geological disasters), HFG also holds significant social relevance (Larder et al., 2014). Participating in HFG enables urban dwellers to forge stronger social connections with their neighbors, thereby increasing the cohesion of gated communities. This is achieved through the distribution or bartering of excess homegrown fresh food. Additionally, individuals engaging in HFG experience direct pleasure and find relief from mental or psychological health problems through the cultivation process (Machida, 2019; Diekmann et al., 2020; Corley et al., 2021; Mullins et al., 2021; Cerda et al., 2022; Sia et al., 2022, 2023). In reality, HFG has an irreplaceable role in horticultural therapy. Engaging in HFG, for instance, can effectively alleviate loneliness, bolster mental resilience, and cultivate tranquility to reduce the incidence of depression and anxiety for the elderly who adore horticulture but lost their arable patches in emigration or urban sprawl, as well as substantial contemporary young white-collar workers with extremely fast-paced lives and chronically high-pressure jobs but do not have access to affordable pastime in densely populated metropolitan areas (Abass et al., 2018; Burgin, 2018).

Gaining delight and achieving sense of accomplishment via growing horticultural crops for aesthetic purposes, helping parents educate their children about agricultural production and bridge the

Abbreviations: Bt, *Bacillus thuringiensis*; EM, effective microorganism; HFG, home food gardening; IoT, internet of things; WBEEP, whole-body edible and elite plant.

gap between kids and nature, as well as harvesting edible horticultural crops for domestic consumption are the prime motivator to engagement in HFG before, during, and after the COVID-19 pandemic (Taylor et al., 2017; Diekmann et al., 2020; Lal, 2020; Chalmin-Pui et al., 2021; Perez-Lugones et al., 2023). A varied and colorful home garden decorated with various vegetables and fruits may be turning into a common sight in the future (Santos et al., 2022). In addition, from an ecological perspective, HFG can lessen the impact of heat islands, ameliorate residential microclimate, as well as contribute to conservation and maintenance of diversity of plants with local characteristics (Furlan et al., 2017; Saroinsong et al., 2021; Hong and Zimmerer, 2022; Patel et al., 2022; Humaida et al., 2023; Korpelainen, 2023; Visvanathan et al., 2023).

The primary focus of this review is to gather and discuss the most recent reports on the developments and problems related to HFG found in the scientific literature. It also suggests viewpoints based on the state of the field in order to serve as a guide for future HFG research and development.

2 Advances

2.1 Cultivated species for HFG

In comparison to seeds grown in farmlands, seeds grown in home gardens should exhibit greater in variety, be easier to cultivate, adapt well to residential environments (e.g., tolerate urban heat), wrapped in smaller packages, and not require large spaces (Richardson and Arlotta, 2022; Cruz et al., 2023). Urban farmers who are disconnected from the land often turn to the Internet for advice on cultivating plants. As a result, many content creators and Internet celebrities who are knowledgeable about HFG (HFG-savvy) share their extensive experience and suggestions through various social media platforms such as YouTube, Bilibili, TikTok, RED, Twitter, and Facebook. These HFG-related works cover a wide range of edible plants, including root vegetables and crops (e.g., onion, turnip, radish, potato, sweet potato, carrot, and ginger), liana and fruit vegetables (e.g., melon, watermelon, cucumber, tomato, eggplant, chili pepper, and Japanese pumpkin), leafy vegetables (e.g., basil, rosemary, thyme, coriander, romaine lettuce, spinach, water spinach, cabbage, savoy, kale, garlic seedling, spring onion, Chinese chive, and scallion), sprouts (e.g., mung bean sprout, soybean sprout, pea sprout, and broccoli sprout), berry fruits (e.g., strawberry, blueberry, and raspberry), and citrus fruits (e.g., kumquat and lemon).

Additionally, the selection of HFG varieties depends on climates, seasons, available spaces and other conditions (Baliki et al., 2023; Cruz et al., 2023). For instance, some heat-tolerant vegetables like water spinach (*Ipomoea aquatica* Forssk.) (Khosa et al., 2023), and okra (*Abelmoschus esculentus* L.) (Khan et al., 2022), can be cultivated during summer. During winter, hardy vegetables like spinach (*Spinacia oleracea* L.) (Yoon et al., 2017), and Chinese chive (*Allium tuberosum* Rottl. ex Spr.) (Wang et al., 2024) can be selected. In places with insufficient lighting, such as low-rise balconies, poor-light-tolerant vegetables such as Chinese chive (*Allium tuberosum* Rottl. ex Spr.) (Wang et al., 2024), and various sprouts are more appropriate for HFG (Le et al., 2021).

More than 100 edible plant taxa from 25 families which is suitable for HFG were identified previously (Taylor et al., 2017; Boneta et al., 2019; Thamilini et al., 2019; Suwardi et al., 2023). In the following text, we will provide detailed introductions for a selected subset of these plants.

2.1.1 Potato

Potato (*Solanum tuberosum* L.) is considered one of the ideal staple foods for HFG due to its numerous merits. These include: (1) high harvest index, (2) high tuber production, (3) starchy tubers providing ample nourishment, (4) uncomplicated cultivation requirements, (5) adaptability to environmental stresses and low soil fertility, (6) relatively long shelf life, (7) simple food processing demands, and (8) asexual propagation through tubers for steady nutritional component regeneration (Wiersema and Booth, 1987; Coffin et al., 1993; Boivin et al., 2020; Devaux et al., 2021; Liu et al., 2021). Domestic potted potatoes are shown in Figure 1.

Potato is an important food security crop and has long been regarded as a "super food" (Devaux et al., 2021). In the science fiction film "The Martian", the protagonist, an astronaut and botanist played by Matt Damon, grows potatoes to survive on Mars. This fictional scenario is now becoming a potential reality. Chinese scientists have been dedicated to biotechnological advancements in space agriculture and have proposed the Whole-Body Edible and Elite Plant (WBEEP) strategy for potato improvement. This strategy aims to address the inherent problem of toxic solanine in potato plants, specifically in the aerial portions such as stems, leaves, and berries, which are currently inedible (Liu et al., 2021). On the basis of genetic modification that can block the biosynthesis of solanine, the WBEEP-potatoes, whose whole bodies are edible, might be created in the future and subsequently applied in HFG.

2.1.2 Tomato

Tomato (*Solanum lycopersicum* L.), a staple of Italian and Latino cuisines, enriched with essential nutrients and bioactive antioxidant compounds, has become a worldwide vegetable (or fruit, as some insist) (Perveen et al., 2015). Statistically, in the United States, among all HFG vegetables, tomato is the most popular one (Cruz et al., 2023). Non-miniature tomatoes with indeterminate growth characteristics require the application of plant growth regulators (e.g., paclobutrazo) to achieve compact potted plants for HFG (Melo et al., 2018; Cruz and Gómez, 2022). In comparison to non-miniature counterparts, dwarf or miniature tomatoes (Figure 2) have smaller plant canopy diameters, shorter internodes, and pedicels. These features offer several advantages, including strong resistance to lodging damage, suitability for diminutive space, and the absence of pruning requirements, which are crucial for HFG (Melo et al., 2018; Zhao et al., 2023). Several dwarf and semi-dwarf tomato varieties with well-proportioned plant architectures and eaten fruits, such as "Micro Gold" (Zhao et al., 2023), "Micro Tom" (Ke et al., 2022), "Red Robin" (Richardson and Arlotta, 2022), "Sweet 'n' Neat" (Richardson and Arlotta, 2022), "Terenzo" (Richardson and Arlotta, 2022), "Tiny Tim" (Richardson and Arlotta, 2022), and "Tumbler" (Richardson and Arlotta, 2022), have been developed as HFG tomato varieties. In addition, a study demonstrated that "Terenzo" and "Tumbler" achieve the highest yield, while "Micro Tom" is the least productive variety among six dwarf tomato cultivars, including "Micro Tom", "Red Robin", "Sweet 'n' Neat", "Terenzo", "Tiny Tim", and "Tumbler" (Richardson and Arlotta, 2022).

2.1.3 Leafy vegetables

Leafy vegetables have a short growth cycle and are essential sources of required vitamins and minerals for human beings (Yoon

FIGURE 1
Domestic potted potatoes.

et al., 2017). Figure 3 illustrates the abundant options of leafy vegetables used for HFG. As a layperson-friendly vegetable, romaine lettuce (*Lactuca sativa* L. var. *longifolia*) grows fast and can easily be cultivated in human settlements using soil culture, substrate culture, or hydroponics (Majid et al., 2021; Noh and Jeong, 2021). A handful of leafy vegetables used for spices are also suitable for HFG, for instance, basil (*Ocimum basilicum* L.) and rosemary (*Rosmarinus officinalis* L.) (Aditya and Zakiah, 2022; Kim et al., 2022). Basil, also referred to as "more precious than gold" or "nine-storey tower" in China, is the main ingredient of Chinese cuisine such as Three Cup Chicken and Italian Pesto sauce (Tanzilli et al., 2023), and rosemary is routinely used for shish kebabs and beef steaks.

2.1.4 Sprouts

Sprouts (i.e., microgreens), a novel class of edible veggies harvested and consumed at an immature stage (Teng et al., 2023). As shown in Figure 4, with small plant sizes, sprouts are advantageous when planted in tiny balcony, kitchen windowsill or other compact places because of their better spatial efficiency (Teng et al., 2023). Additionally, sprouts are non-polluting green foods produced directly from seeds, have no intricate cultivation demands, and can be grown in soil or hydroponically in both light and dark environments (Reed et al., 2018; Le et al., 2021; Xiao et al., 2022). Healthwise, as functional edibles with anti-oxidant powerhouse credited with preventing some diseases, sprouts deliver richer nutrition than seeds, since they contain high levels of carbohydrates, dietary fibers, amino acids and health-beneficial metabolites like polyphenols (Zhang et al., 2022; Nolasco et al., 2023; Suathong et al., 2024; Zhao et al., 2024). Moreover, nutrient-rich food sprouts have been found to grow faster and can be harvested earlier compared to other vegetables. This quality makes them particularly valuable during times of major disruptions in the fresh product supply chain, as they effectively ensure the intake of required vitamins (Reed et al., 2018; Zhang et al., 2022). Hence, sprouts have captured more attention from HFG hobbyists with health consciousness (Supapvanich et al., 2019; Gilbert et al., 2023).

Traditional legume seed sprouts, such as pea sprouts (*Pisum sativum* L.), are widely consumed and highly popular in various regions around the world. They are particularly favored in Southwest China, including Sichuan Province and Guizhou Province, as well as in several Asian countries like Japan, Korea, and Thailand. This popularity can be attributed to their desirable qualities, including crispness, tenderness, fresh fragrance, and significant nutritional value (Lin et al., 2023; Suathong et al., 2024). In recent years, plentiful novel sprouts with functions differed from legume seed sprouts are emerging, such as the broccoli sprouts rich in glucosinolates and sulforaphane (Guo et al., 2016), the coriander sprouts rich in phylloquinone and tocopherols (Rajan et al., 2019), and the rapeseed sprouts rich in glucosinolates and selenium (Xiao et al., 2022), the presence of these sprouts greatly expands the choices for HFG, and provides urbanite with more comprehensive nutrition.

2.1.5 Strawberry

Fruits are an important component of the human daily diet, but HFG fruits available are obviously few compared with vegetables. Strawberry (*Fragaria* × *ananassa* Duch.), a perennial herb, cultivated worldwide due to the vibrant color, fragrant flavor, succulence, distinctive sweetness, high nutritional value (e.g., rich in minerals, vitamins, anthocyanins, carotenoids, and polyphenols) and health benefits, is ideally suited for HFG owing to their small size and relatively lower light requirements (Tulipani et al., 2011; Battino et al., 2021; Hardigan et al., 2021; Martín-Pizarro et al., 2021; Wang et al., 2022; Avendaño-Abarca et al., 2023; Zheng et al., 2023; Liu et al.,

FIGURE 2
Domestic potted dwarf tomatoes.

2024). Domestic potted strawberry cultivation is shown in Figures 5A,B. The trend of HFG opens a novel dimension to strawberry cultivation (Olbricht et al., 2014). Besides common white-flowered strawberries, there are also red-flowered and pink-flowered varieties that have been developed through distant hybridization (*Fragaria* × *Potentilla*), which have gained popularity among urban gardeners for their use in landscaping and potted viewing (Ding et al., 2019; Liu et al., 2021). A pink-flowered strawberry cultivar is shown in Figures 5C,D. As eye catchers, the red-flowered and pink-flowered strawberries with unique flower morphological characteristics (e.g., semi-double flowers in succession), diverse petal colors (i.e., covers the whole red series, flower colors range from light pink to deep red), relatively long florescence, strong ability to reproduce, edible and ornamental values are "add flowers to the brocade" for HFG, commanding a markedly higher selling price and economic value distinguished from common white-flowered strawberry varieties (Xue et al., 2016; Ding et al., 2019; Xue et al., 2019; Guan et al., 2023). Actually, there is an immense market potential for ornamental strawberries in the post-epidemic era (Guan et al., 2023).

With a history of over 60 year efforts in modern ornamental strawberry breeding, breeders have successfully developed a broad assortment of pink-flowered and red-flowered strawberry cultivars with independent intellectual property rights (Mabberley, 2002; Khanizadeh et al., 2010; Xue et al., 2015; Ding et al., 2019; Bentvelsen and Vange, 2021; Yue et al., 2022; Guan et al., 2023). For instance, ABZ Seeds, a Dutch breeding company dedicated to the development of F1 hybrid seed-propagated strawberry cultivars, has delved into ornamental strawberry breeding and released a series of superior ornamental strawberry varieties full of aesthetic morphological attributes, such as "Summer Breeze Cherry Blossom", "Summer Breeze Rose", "Gasana" and "Toscana" in the market (Bentvelsen and Bouw, 2006; Bentvelsen and Vange, 2021). Table 1 provides an overview of the some institutions involved in ornamental strawberry breeding and the varieties they have developed.

2.2 Devices available for HFG

Actually, some kind of cultivation points, such as precise or appropriate fertilization, irrigation, temperature and light managements, are hard to novices of HFG. Thus, inexperienced urban gardeners require suitable equipment that is not difficult to utilize. Some novice-friendly cultivation systems, which can automatically and continuously adjust environmental conditions, including

FIGURE 3
Leafy vegetables cultivated in residences.

FIGURE 4
Self-production of sprouts at home.

FIGURE 5
Domestic potted strawberries **(A)** and **(B)**, a pink-flowered strawberry cultivar **(C)** and **(D)**.

photoperiod, light intensity, humidity, temperature, soil moisture level and nutrient solution irrigation. These systems help minimize environmental fluctuations and achieve precise control over the plant growth environment (Kim et al., 2022). Currently, there are four cultivation patterns of HFG, including soil culture, substrate culture, hydroponics, and aquaponics (Kyaw and Ng, 2017; Suárez-Cáceres et al., 2021; Richardson and Arlotta, 2022). In fact, almost all HFG plants can be grown in the soil and substrate. Some plants suitable for hydroponics at home and their cultivation points are shown in Table 2 (Baras, 2018). Plants suitable for hydroponic cultivation are also suitable for aquaponics.

2.2.1 Light supplementation equipment

Plant growth and development are significantly influenced by light since it has an impact on the energy metabolism of plants. Insufficient exposure to light during plant growth hinders carbon dioxide (CO_2) absorption and assimilation, which lowers photosynthetic efficiency and impacts agricultural productivity (Deng and Deng, 2018). However, a typical issue in HFG is inadequate lighting, especially on low-rise balconies where low-intensity scattered light is the norm, thus light supplementation is very important. Traditional light supplementation devices are considerably power-consuming. Daylight harvesting is a technique extensively utilized in protected agriculture, which can effectively modulate supplemental lighting been based upon sunlight (Bhuiyan and van Iersel, 2021). Some individuals interested in new things opt for high-end automated machines equipped with advanced features such as plant lighting devices with daylight harvesting capabilities. These devices have an intelligent adjustable light function that emits supplemental light based on photosynthetic active radiation. They are particularly useful for HFG plants that are typically deprived of sunlight in balconies or other areas. For instance, a novel micro indoor smart hydroponics system, named Adpatalight, utilizes Internet of Things (IoT) technology. This system harvests ambient light by utilizing an inexpensive AS7265x IoT sensor to measure photosynthetic active radiation, resulting in a significant reduction in energy consumption (Stevens et al., 2022).

2.2.2 Substrate cultivation system

Soil-based HFG may pose a contamination risk due to urban soil, besides, low fertility, low organic matter, decreased activity and diversity of soil organisms, as well as high concentrations of stones, gravels, and artifacts are frequently found in urban soils. These elements may have a detrimental effect on horticultural crop productivity, rendering urban soils unsuitable for HFG, therefore, utilizing inert and clean substrates is an effective solution (Ercilla-Montserrat et al., 2018; Izquierdo-Díaz et al., 2023). Spanish researchers found that the output of a open-air rooftop soilless home food garden based on perlite bag culture, can achieve a high degree of self-provisioning for a two-member household (Boneta et al., 2019). Now in China, there are some substrate-based vertical system used for HFG, two of them are shown in Figure 6.

2.2.3 Hydroponic systems

The discrepancy between hydroponics and traditional cultivation is that hydroponics has no demand for plowing field and weeding, also, it can reduce even eliminate the application of pesticides, making HFG more feasible and convenient in urban settings where space is

TABLE 1 Some breeding institutions of ornamental strawberry and their bred varieties.

Breeding institutions	Varieties	References
ABZ Seeds	Florian	Bentvelsen and Vange (2021)
	Frisan	
	Gasana	
	Merlan	
	Pikan	
	Red Ruby (i.e., Feanor)	
	Roman	
	Ruby Ann	
	Summer Breeze Cherry Blossom	
	Summer Breeze Rose	
	Tarpan	
	Toscana	
	Tristan	
Agriculture and Agri-Food Canada, Horticulture Research and Development Center	Rosalyne	Khanizadeh et al. (2010)
	Roseberry	
Jiangsu Academy of Agricultural Sciences	Zijin Fenyu	Guan et al. (2023)
	Zijinhong	
Shenyang Agricultural University	Fenyun	Yue et al. (2022)
	Pink Beauty	Ding et al. (2019)
	Pink Princess	
	Pretty Beauty	
	Red Rose	Xue et al. (2015)
	Sijihong	Guan et al. (2023)
	Xiaotaohong	
University College London	Pink Panda (i.e., Frel)	Mabberley (2002)

TABLE 2 Some plants suitable for hydroponics at home and their cultivation points.

Plants	Optimum temperature (°C)			Optimum pH of nutrient solution	Optimum electrical conductivity of nutrient solution (ms/cm)
	Germination	Nutrient solution	Air		
Basil	18–24	21–24	21–27	5.5–6.0	1.8–2.3
Capsicum	24–27	18–21	24	5.5–5.8	1.4–1.8
Kale	24–30	15–24	15–33	5.5–6.5	1.2–2.3
Lettuce	15–21	18–21	18–24	5.5–6.0	1.8–2.3
Spinach	7–18	10–21	18–24	5.5–6.0	0.7–2.3
Strawberry	21	15–21	15–27	5.5–6.0	0.8–1.2
Tomato	24–27	18–24	15–24	5.5–6.0	1.2–2.5

limited (Solis-Toapanta et al., 2020; Noh and Jeong, 2021). In actuality, hydroponic systems include aeroponics, wick watering, DWC (Deep Water Culture), DFT (Deep Flow Technique), NFT (Nutrient Film Technique), and more. The wick watering system is the most basic and low-maintenance of all the hydroponic systems. Because of this, it works well for small plants like lettuces and strawberries and is therefore more appropriate for HFG. Furthermore, hydroponics combined with a vertical system can achieve higher yield of leafy vegetable production in a compact space (Rajan et al., 2019), two hydroponic systems are shown in Figure 7. In a recent development, Malaysian scientists have introduced a smart hydroponic system called SMART GROW, which utilizes Internet of Things (IoT) technology. This system offers several advantages, including minimal space requirement, cost-effectiveness, automated water level regulation, and the ability to cultivate various edible plants at home (Shin et al., 2024).

FIGURE 6
Two vertical substrate-based systems used for leafy vegetables.

FIGURE 7
Two vertical hydroponic systems used for leafy vegetables.

2.2.4 Aquaponics equipment

Aquaponics, considered as a bio-integrated system mimicking a complex ecosystem, is composed of beneficial bacteria (e.g., heterotrophic bacteria and nitrifying bacteria), recirculating aquaculture and hydroponic cultivation (Wongkiew et al., 2017). This environmentally friendly system utilizes the nitrogen in aquaculture effluent as nutrients for hydroponic plant growth. At the same time, the plants purify the water, creating a suitable environment for the culture of aquatic animals such as pearl gourami (*Trichogaster leerii*), carp (*Cyprinus carpio*), tilapia (*Oreochromis mossambicus*), catfish (*Clarias gariepinus*), and shrimp (*Litopenaeus vannamei*). By combining these elements, aquaponics effectively addresses the individual limitations of each component (Makhdom et al., 2017; Wongkiew et al., 2017; Pineda-Pineda et al., 2018; Goddek and Keesman, 2020; León-Cañedo et al., 2023). Aquaponics has gained rapid development and wide application in home food production due to its high resource utilization rate, absence of chemical fertilizers and antibiotics, low consumption, high efficiency, and sustainability (Kyaw and Ng, 2017; Wongkiew et al., 2017; Li et al., 2018; Suárez-Cáceres et al., 2021). A study has shown that aquaponics can provide equal or higher nutrient content for lettuce compared to traditional hydroponics. Additionally, the highest lettuce yield was achieved when treating with 120% of the recommended fish diet (Pineda-Pineda et al., 2018).

A smart aquaponics system has been designed and developed by scientists in Singapore for HFG. The system is primarily used for producing water spinach and raising tilapia (Kyaw and Ng, 2017). Equipped with various sensors, actuators, microcontrollers, and microprocessors, the system is able to monitor and regulate water quality, light intensity, and aquatic animal feed (Kyaw and Ng, 2017). If any abnormal system state is detected by the sensors, the user will automatically receive early warnings from the system, and the actuators will rectify the abnormal conditions without any human intervention (Kyaw and Ng, 2017). The dispensing of aquatic animal

feed is done according to the user's preset timings (Kyaw and Ng, 2017). The extent of self-provisioning in aquaponic systems is heavily dependent on their size. In the past, achieving a high degree of self-sufficiency from a small-scale aquaponic system was considered nearly impossible due to space constraints and limited productivity. However, recent advancements have led to significant progress in this area. Researchers in Spain have successfully developed two micro-scale domestic aquaponic systems, which consist of a 4.56 m^2 cropping area and a 1 m^3 fish tank. Excitingly, the results of their study demonstrated that these home-based aquaponic systems can annually produce 62 kg of tilapia and 352 kg of 22 different agricultural products, including tomatoes, peppers, melons, pumpkins, cucumbers, basil, broccoli, cabbage, Chinese cabbage, onions, chard, and lettuce (Suárez-Cáceres et al., 2021). The output can provide self-sufficiency along with dietary diversity for a four-member household throughout the year (Suárez-Cáceres et al., 2021). Compared to other cultivation patterns like the rooftop system mentioned earlier, aquaponics is more likely to have higher productive efficiency in supporting self-provisioning (Boneta et al., 2019).

2.2.5 Sprouts production devices

Paper-based sprout garden is a system suitable for home-grown sprout production, it is based on a piece of absorbent paper with watering at regular intervals and can harvest after 10 to15 days of growth given the optimum environments. At present, there are multifarious grow plates and racks available for picking on the basis of spatial layout of residence (Li et al., 2023). Additionally, for those new to sprout cultivation, user-friendly microgreen growth kits like the one introduced by Hamama, Inc. are also recommended options (Teng et al., 2023).

2.3 Technologies available for HFG

2.3.1 Hydroponic technologies

The constituents of the nutrient solution have a significant impact on the yield and quality of hydroponic crops. Ssamchoo (*Brassica* lee ssp. *namai* cv. Ssamchoo) is a vegetable commonly used in Ssam, a Korean specialty food. However, cultivating Ssamchoo hydroponically poses challenges due to its sensitivity to the composition and concentration of the nutrient solution (Noh and Jeong, 2022). A research reported that nutrient solution (the ratio of NO_3^- to NH_4^+ to urea is 50: 25: 25) combined with silicon (10.7 mmol L^{-1}) is suitable for planting Ssamchoo in a household hydroponic system. This optimized nutrient solution not only allows for achieving the highest yield but also effectively mitigates the harmful effects of ammonium on Ssamchoo (Noh and Jeong, 2022).

2.3.2 Ordinary home composting and black soldier fly larvae-based composting technologies

High-quality soils are often not readily available in urban residential areas. In addition, soilless substrates used for HFG typically lack sufficient nutrients. Therefore, it is essential to enhance soil fertility and functionality by applying some fertilizers, such as chemical fertilizers, homemade composts or commercial organic fertilizers (Lal, 2020; Shrestha et al., 2020; Dorr et al., 2023). For cutbacks in expense of chemical fertilizers and organic composts used for HFG, many urban gardeners opt to prepare small-scale home composts themselves (Gao et al., 2022). Biodegradable kitchen waste, such as meat or fish scraps, and urban green waste, such as fallen leaves and chopped grasses, can be transformed into valuable assets through the production of home-made composts. This practice aligns with the principles of a circular economy and sustainable agriculture (Storino et al., 2016; Hou et al., 2024).

Effective Microorganism (EM), originated from Japan, is one of the useful additives for composting (Fan et al., 2018). A research revealed that the practice of home-scale composting inoculated with the activated EM, is able to significantly reduce the smelly odor during the decomposition, promote humification of raw composting materials, as well as increase the decomposition rate of fat (Fan et al., 2018). In another study, it was found that regular urban gardeners were able to effectively compost kitchen waste indoors by adding EM and lime at a rate of 1% of the wet weight of the feedstock. This homemade compost also led to improved seed germination for most families (Gao et al., 2022). *Bacillus thuringiensis* (Bt) is a pathogen with potent pesticidal activity (Jurat-Fuentes et al., 2021). More recently, Spanish researchers have presented an approach to produce Bt-enriched home-scale compost through an uncomplicated procedure and low-input process (Ballardo et al., 2020). The efficiency of home composting also need to be focused on. A study demonstrated that a period of 12 to 15 months may be suitable for the development of home composting (Tatàno et al., 2015). However, another research reported that it only takes 21 days to convert food wastes to composts just with minor alkalinity (Margaritis et al., 2023). The discrepancy between these two studies could be attributed to the varied additives used.

Actually, compare to time-consuming composting, there is a more efficient approach to kitchen waste treatment—black soldier fly larvae-based composting (Nguyen et al., 2015). Black soldier fly (*Hermetia illucens* L.) is an insect commonly utilized for the bio-conversion of kitchen waste. Its larvae efficiently convert various organic wastes into nutritious insect proteins and fats, while also reducing the content of antibiotics and decreasing the abundance of resistance genes commonly found in ordinary home-produced composts (Liu et al., 2017; Cai et al., 2018; Liu et al., 2020). As a fat-rich and protein-rich feed source, black soldier fly larvae can be used for feeding aquatic animals if small-scale aquaponic systems are already equipped in the residence (Qiu et al., 2023).

2.3.3 Light and temperature management technology

Regulating photoperiod and temperature can be beneficial for urban gardeners in effectively controlling the growth and harvest time of HFG plants. According to Korean scientists, for romaine lettuce (*Lacteal sativa* L. var. *longifolia*), a temperature setting of 25/18°C together with a photoperiod of 14 h were the most suitable for hastened growth. On the other hand, a temperature of 20/15°C combined with an 18 h photoperiod was deemed suitable for delayed growth (Noh and Jeong, 2021).

2.3.4 Domestic sprouts production technology

While it is advisable to minimize the use of chemical agents, it is crucial to apply them judiciously in order to achieve high yields and ensure the safety of harvested produce in HFG systems (Gilbert et al., 2023). For instance, employing safe chemicals such as dilute domestic

bleach (0.6% sodium hypochlorite) and freshly generated hypochlorous acid (800 ppm chlorine) for seed disinfestation practices can effectively suppress seed-borne bacterial and fungal infections, thereby preventing food contamination (Ding et al., 2013; Gilbert et al., 2023).

3 Current issues

3.1 Space constraints

Actually, a substantial private backyard is an ideal place to implement HFG. However, with urban consolidation, more lands are being occupied, leading to a reduction or elimination of backyards. Consequently, the available space suitable for HFG has significantly decreased (Burgin, 2018). Deficiency of enough space outdoors has become the main barrier to implement home composting, thus, HFG are transferring indoors (Deng and Deng, 2018; Kunszabó et al., 2022; Cruz et al., 2023). Nonetheless, owing to the dramatically enhanced density of housing, along with the urban space is at a premium in megacities, a great deal of housing estate developers presently are apt to omit home gardening areas, mainly residential balconies and terraces. Instead, they allocate more space for other public landscapes like lawns for exercise and street trees, or for car-parking bays in new housing schemes, consequently potential spaces for HFG is more compact than some existing old residential quarters, and in some cases, there may be no space available at all (Burgin, 2018; Chalmin-Pui et al., 2021). A more demise of the spaces for HFG occurred worldwide, as a consequence, HFG is considered a luxury in particular in several megacities nowadays, as well as most often the purview of the "upper class" rather than the "middle class" and "working class", simultaneously, making plant architecture that has excellent adaptability in a small volume space become the most ideal plant architecture and highest priority breeding objective for HFG (Burgin, 2018; Cruz et al., 2023; Ma et al., 2023). Besides, the demand of wall-type cultivation infrastructure used for HFG is also increasing because of space constraints.

3.2 Underlying harms for buildings

When implementing HFG, the construction of balconies and terraces in most buildings poses new challenges in terms of building loading capacity, leak proof systems, waterproofing, and drainage. This is mainly because these areas were not originally designed to accommodate the necessary supporting infrastructures for HFG. In other words, the planning field was previously unaware of the specific requirements of HFG (Burgin, 2018). In addition, there is a risk of soil and substrate leakage from planting containers, which can potentially cause blockages in residential drainage pipes.

3.3 Lack of government policy support

The initiatives for urban HFG have been predominantly driven by governments. Many countries, such as Australia, are addressing the lack of space for HFG with the support of governmental agencies (Burgin, 2018). However, in developing countries, government policy support for HFG is rare. Interestingly, in Australia, certain local governments like Canberra, Brisbane, and Perth, are even permitting adjacent household owners to use street areas for HFG, which is hard to imagine and achieve elsewhere (Burgin, 2018). Actually, soil-based or substrate-based HFG heavily relies on compost-derived nutrients, with meat scraps being a crucial feedstock for homemade compost. However, it is important to note that in certain European countries, composting meat waste is prohibited due to regulations such as the Animal By-Products regulation (Storino et al., 2016).

3.4 Labor- and time-intensive procedures

Without a doubt, some HFG practices are labor-and time-intensive. These include pruning, weed removal, replacing soil, and providing ongoing care for HFG crops over their whole life cycle. For some leisurely people who embrace HFG and can allocate adequate time to tend to plants, like retired elderly people in good physical condition, it provides gentle exercise together with joy. However, for others who find it difficult to take time away from their regular housework or work, such as exhausted working mothers who wear two hats, HFG can be a source of real torture (Perez-Lugones et al., 2023). Obviously, it is not a consideration of busy people unless some of ones are obsessed with HFG.

3.5 Relatively high input costs

Throughout history, the main motivation for low-income home gardeners to grow agricultural products instead of purchasing in the market, increases substantially in times of economic crisis or situations with economic downturn (Burgin, 2018; Perez-Lugones et al., 2023). But more recently, a number of cases are against the original intention. Some newly designed devices used for HFG is costly with low efficiency. For example, micro indoor smart hydroponics systems designed by a research team consisting of scientists from United Arab Emirates and Australia, have the apparently prohibitive costs in power consumption and equipment expense (Stevens et al., 2022).

3.6 Deficiency of planting experience

In general, urban horticultural neophytes do not have much knowledge that how to carry out HFG in an appropriate approach (Oberholtzer et al., 2014; Kunszabó et al., 2022). Novice home gardeners frequently encounter issues such as root maceration due to excessive irrigation, seedling burn caused by overfertilization, and phytotoxicity resulting from improper pesticide and fungicide concentrations. Despite their efforts to learn various planting techniques, urban gardeners still face significant knowledge gaps. Certain crops, like tomatoes and eggplants, require complex pruning throughout their growth period to avoid a tangle of branches and leaves and to ensure optimal fruit yield (Srinivasan and Huang, 2009; Appolloni et al., 2023; Wang et al., 2023). While young city dwellers have relatively easy access to planting experience and techniques, the elderly, especially those without electronic equipment or proficiency in its use, struggle to obtain planting knowledge.

FIGURE 8
Collection of mystery box tomato fruits (primarily cherry tomatoes).

3.7 Unguaranteed seed quality, vanishing heirlooms, and scarcity of cultivar selection information

Contemporarily, a switch from a preference for inedible ornamental plants to fruit seedlings and vegetable seeds has occurred among urbanite (Perez-Lugones et al., 2023). However, there is a shortage of specialized varieties for HFG, which hinders its widespread adoption and application (Sykes et al., 2021). Mystery boxes are much the rage today in China. In the context of HFG upsurge, mystery seed boxes or blind seed boxes (i.e., randomly selected different seed varieties that are mixed in a package) have gripped consumers, becoming one of the bestsellers on e-commerce platforms due to the pleasure surprise. As shown in Figure 8, mystery box tomato fruits exhibit different phenotypes. However, there is a considerably obvious downside to mystery seed boxes purchased from some online stores. The pedigrees of these seeds are typically unknown, and they may consist of segregating individuals or hybrids. As a result, the taste, yield, tolerance against environmental stresses, and resistance to pathogens and pests cannot be guaranteed (Ma et al., 2023). Actually, there are two main reasons hindering the development of the seed industry for HFG, one significant constraint is that parts of the urban residents lean toward getting access to the seeds free of cost, and another is that the market size of HFG plants is not big enough (i.e., on small-scale) to give impetus to the research and development of HFG species (Ma et al., 2023).

In order to achieve commercialization, the majority of seeds available for sale are hybrid seeds. These seeds are unable to produce viable seeds in the second generation due to the presence of multiple divergent characteristics in the fruits, such as varied colors, shapes, sizes, flavors, and textures (Osmani et al., 2023). Therefore, growers are required to purchase new seeds every year, particularly in regions with well-established formal seed systems (Osmani et al., 2023). In contrast, heirloom varieties can be preserved by seed owners for generations (Jordan, 2007). It is worth noting that while hybrid seeds are often favored for their resistance and productivity, there are some heirlooms that are widely grown and sold and are considered to have superior flavor compared to commercial hybrid varieties (Joseph et al., 2017; Tieman et al., 2017). From the perspective of some relatively nonwealthy or needy amateur gardeners apt to cut the cost of seeds and preserve seeds themselves, heirlooms can be excellent choices, albeit this may slightly dampen the breeding enthusiasm of some breeders. However, every coin has two sides, indeed, those heirloom varieties bearing a wide diversity of colors, shapes, resistances, flavors and other traits can be utilized by breeders targeting to improve crop properties, such as flavor, mouthfeel, appearance and other organoleptic traits (Jordan, 2007; Joseph et al., 2017). Nowadays, in several European countries, Australia and North America, heirloom varieties are ordinarily sold in the market, but in China, they are vanishing gradually (Joseph et al., 2017; Burgin, 2018; Constantino et al., 2022). Consequently, now there is before agriculture professionals an imperative than previously in collection, preservation, and resurgence of precious heirlooms for posterity. In addition to official efforts, a non-governmental team in China called Seed Hunter is dedicated to reviving heirlooms. In aggregate, more efforts are required for the preservation and utilization of heirlooms.

As is known to all, in different geographical settings, regionally-appropriate plants are varied. As a result, knowledge based on research on regionally-specific varieties is extremely valuable and may serve as a reliable source of reference for novices in HFG when they come to choosing and caring for plants (Sykes et al., 2021). However, regional performance assessment data of HFG plants are now extremely rare due to the high cost of experiments but lack of relevant financing and a scarcity of researchers in the unheeded field (Sykes et al., 2021).

3.8 Weak light and changing weather conditions

Photosynthesis is vital for plants, the stronger the light, within a certain range of light intensity, the higher the photosynthesis rate (Deng and Deng, 2018). However, poor light is a common hurdle in HFG, particularly on low-rise balconies where low-intensity scattered light predominates. This makes many crops less productive, including tomatoes, which need a much higher daily light integral than most leafy vegetables (Burgin, 2018). Compact pepper and tomato cultivars are widely used for HFG, however, research has shown that indoor UV radiation deficiency typically causes compact pepper cultivars to become susceptible to intumescence, significantly lowering the aesthetic value of pepper seedlings (Cruz et al., 2023; Suarez et al., 2023). Climate change has caused extreme weather to occasionally affect protected fields, not to mention HFG sites without shelter. Typhoons, frosts, hailstorms, and heat injuries have become commonplace, making it difficult for HFG to operate outdoors and ultimately leading to a failure to improve food self-provisioning (Du Toit et al., 2022; Darge et al., 2023).

3.9 Annoying pests, phytopathogens, and birds

Pests, phytopathogens and birds exact a toll on HFG (Scott et al., 2004; Depenbusch et al., 2022). For instance, vegetables and fruits, especially with vibrant color, like tomatoes and strawberries grown in the open-air balconies and terraces without application of insect-proof screens, are frequently eaten by birds (Figure 9). Furthermore, pests like western flower thrips, aphids, spider mites, and leaf miners, as well as phytopathogens like *Botrytis cinerea* and *Alternaria solani*, can cause frustration for horticultural beginners (Perez-Lugones et al., 2023). The heavy soil and the relatively high cost of commercial substrate make many urban growers reluctant to replace them, leading to obstacles in continuous cropping unless comprehensive disinfection and appropriate crop rotation are implemented.

3.10 Poor quality of urban soils

In situations where space is no allotment, urban gardeners may resort to creating small-scale gardens like roof gardens, and implementing HFG with domestic cultivated containers (Burgin, 2018; Baliki et al., 2023). But urban individuals usually have no soil in their homes. Due to budget constraints, most of them are inclined to collect soil adjacent to residential dwellings. The proliferation of HFG is a contributing factor to paying close attention to urban soil quality by part of citizens. Urban soils are often characterized by compaction, low fertility, limited organic matter, reduced activity and diversity of soil organisms, and high levels of stones, gravels, and artifacts. These factors can negatively impact the productivity of horticultural crops, making urban soils unsuitable for home food production (Lal, 2020).

FIGURE 9
Tomatoes and strawberries pecked by birds.

3.11 Health risks, even life dangers

Sometime, HFG may result in some disease dissemination, for example, Australian scientists revealed that toxigenic *Clostridium difficile* present in the home garden environment (e.g., soil, compost, and manure) contributes to the *C. difficile* infection in the community, which may lead to diarrhea, and even severely result in death (Shivaperumal et al., 2020).

Ventilation can result in heat losses, especially on cold days (Tien et al., 2021). During winter, people often reduce the frequency of ventilation to maintain ambient temperature, particularly at night. However, indoor farming plants serve as effective air purifiers during the day, releasing oxygen and reducing air pollutants such as formaldehyde, toluene, and benzene from new furniture and household decorations. It is important to note that these plants also produce CO_2 at night (Deng and Deng, 2018; Kumar et al., 2023). Without or lack of periodic ventilation, combined with CO_2 generated by human respiration, CO_2 will accumulate soon in indoor space. Evidence showed that elevated concentration CO_2 in human-residing environment may result in attention deficit, fatigue, and drowsiness (Wyon, 2004). Indeed, as a crassulacean acid metabolism plant, aloe (*Aloe vera* L.) is one of ideal indoor HFG plants, which can continuously absorb CO_2 during the night (Winter et al., 2005).

As widely acknowledged, falling objects pose a significant threat, with severe cases even leading to fatalities (Grivna et al., 2015). In adverse weather conditions such as typhoons, potted plants lacking adequate stabilization are prone to toppling and causing potential hazards.

Urban soils in industrialized cities can contain high levels of contaminants, such as heavy metals and organic pollutants (e.g., petroleum hydrocarbons, antibiotics, microplastics), which can be emitted from sources like automotive exhaust. These contaminants have the potential to accumulate in the human body when consuming food grown in polluted soils, leading to various side effects, including carcinogenic risks (Gao et al., 2015; Manucharova et al., 2021; Nematollahi et al., 2022; Zhu et al., 2023; Lange et al., 2024). While food contamination from polluted urban soil can be addressed through the adoption of substrate culture or hydroponics, it is important to note that toxic heavy metals present in the atmosphere of densely populated areas may pose a threat to the safety of home-grown food (Izquierdo-Díaz et al., 2023). Fortunately, theses toxic heavy metal particles primarily adhering to the leaf surface and that their absorption into the plant tissue is limited. Consequently, it is strongly advised to wash vegetables produced in urban gardens in order to minimize the possibility of ingesting toxins that may be adhered to surfaces (Izquierdo-Díaz et al., 2023).

Sprout production involves the seed germination process, which requires warm and moist conditions. However, these ideal conditions also create an optimal habitat for pathogens such as *Salmonella* and *E. coli* O157:H7 to proliferate. As a result, household sprout production is vulnerable to microbial contamination, which can lead to a certain probability of food poisoning and even pose a risk to life (Gilbert et al., 2023).

Nitrate is a main source of nitrogen for crops (Buoso et al., 2021). Excessive fertilization is a prevalent problem in HFG due to the lack of experience among urban inhabitants. In hydroponics, when the nutrient solution contains an excess of nitrate ions beyond the requirements of the crops, leafy species have the potential to accumulate excessive amounts of nitrate ions (Bian et al., 2020). However, high nitrate content in edible portions of crop plants renders harm to people who consume them (Bian et al., 2020). Ironically, the original motivation of several urbanite for carrying out HFG is the ongoing scare that arose from food contamination (Boneta et al., 2019).

While home composting markedly reduces the costs associated with collecting, transporting, and treating kitchen waste, and the use of home-produced compost for soil and substrate amendment is effective, it is important to consider some drawbacks. Urban growers often face issues with foul odors and nauseous leachate during the composting process. Additionally, homemade composts may contain heavy metals and various substances that contribute to antimicrobial resistance, posing risks to human health (Vázquez and Soto, 2017; Kohli et al., 2022; Kunszabó et al., 2022; Hou et al., 2024).

3.12 Water eutrophication

From an ecological perspective, the application of domestic composts often results in an excessive amount of phosphorus being applied, surpassing the nutrient requirements of plants. This can lead to the potential loss of phosphorus through leachate and runoff, ultimately causing water eutrophication (Small et al., 2019; Shrestha et al., 2020).

4 Future perspectives

Historically, the practice of supplementing domestic meals with agricultural products from HFG has "waxed and waned". In the post-epidemic era, the importance of HFG to support the household food self-sufficiency would have diminished in some countries or territories. HFG is no longer solely focused on food self-provisioning, it now encompasses various functions such as decoration, recreation, therapy, socialization, and education. Consequently, there continues to be a growing market and increased popularity of HFG, evident both in the media and real-life scenarios. However, it is important to acknowledge that there are still numerous unresolved issues that need to be addressed.

At present, one of the main obstacles to implementing HFG is the limited space available in residential areas or adjacent to living spaces, due to the increasing trend towards smaller allotments. For the encroachment on HFG spaces as well as omission of HFG spaces by property development, spaces available for HFG should be embedded in housing estates along with other system in building planning design, which requires valid government policy development. Besides, other HFG-related government policy support should be introduced and implemented. In addition, more cultivation facilities that can effectively improve space utilization efficiency should be studied and promoted in the future, such as various wall-type cultivation systems.

In order to cut down HFG expenses, smart devices can be equipped with multiple solar panels to harness solar energy and power the entire intelligent system. Additionally, it is crucial to continuously promote the development of low-cost equipment with highly efficient traits.

Some evidence has shown that addressing the lack of planting experience and techniques can be relatively easy through hands-on training in garden management. Therefore, neighborhood committees of residential compounds, apartments, and townhouses can consider inviting agricultural experts to give lectures for HFG greenhorns.

Besides, breeders could contribute to the welfare of citizens by donating various seeds during public activities. In addition to providing offline instruction, providing more expert online HFG platforms for exchanging problems and answers may be an efficient way to deal with the issue of insufficient planting experience, because online platforms can break the restrict of time and space.

The breeding of HFG special cultivars requires collaboration between breeders and the full utilization of existing plant resources. This is done to diversify horticultural plant genetic resources and continuously enhance the variety of plant species available for residential lots. This provides people with a wider range of colorful and diverse options to appreciate and consume. Similar to cultivation in space, the ideal crops for HFG should be able to provide much sustenance with minimal fertilizer inputs. Therefore, the WBEEP approach should be implemented on other plants, not just limited to potatoes.

In addition to utilization of insect-proof screens, urban gardeners can implement HFG in closed or semi-closed systems to successfully prevent losses in the face of horticultural products being pecked by birds and bitten by pests. Although carrying out HFG in closed systems or semi-closed systems may encounter the challenge of poor light, growers can use supplementary lighting equipment to mitigate this problem.

In aquaponics, the level of dissolved oxygen and nitrate concentration in water should be monitored by some sensors in real time to ensure the development of aquatic animals, and achieve safe home-grown vegetables with low nitrate content, because food safety issues should always be a key concern at all times.

Hygienic issues associated with HFG, such as operation involved in household composting, should be brought into sharp focus. Against the background of HFG boom, developing safe, affordable along with high-efficiency commercialized domestic composters and their accessories (e.g., compost accelerators compatible with the attributes of various types of waste) are of great importance and necessity.

5 Conclusion

As alluded to above, throughout human history, HFG has played a crucial role in self-provisioning, particularly during economic downturns and food shortages caused by emergencies. In an uncertain future marked by war, plague, oil embargo, climate change, and other catastrophic events, HFG is seen as a sustainable and viable approach to ensuring nutrition security. As citizens increasingly recognize the importance of HFG in the 21st century, it is expected to become integrated into their daily lives. Certainly, now HFG is not a silver bullet to cope with urban hunger yet, there are challenges and opportunities that need to be explored and developed further in the field of HFG.

Author contributions

JX: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Visualization, Writing – original draft, Writing – review & editing. TLin: Project administration, Visualization, Writing – review & editing. YW: Project administration, Visualization, Writing – review & editing. WJ: Conceptualization, Writing – review & editing. QL: Visualization, Writing – review & editing. TLu: Writing – review & editing. YX: Formal analysis, Writing – review & editing. JJ: Conceptualization, Funding acquisition, Supervision, Writing – review & editing. HY: Conceptualization, Funding acquisition, Supervision, Writing – review & editing.

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Conflict of interest

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