frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 01 March 2024
DOI 10.3389/fsufs.2024.1267894

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RECEIVED 27 July 2023
ACCEPTED 13 February 2024
PUBLISHED 01 March 2024

CITATION
Ding X, Zhao S, Yue X, Xing Y and Zhao Z (2024) Design factors promoting the benefits of an edible campus in China. *Front. Sustain. Food Syst.* 8:1267894. doi: 10.3389/fsufs.2024.1267894

Design factors promoting the benefits of an edible campus in China

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Currently, most university campuses in China are plagued by issues such as high food demand, imbalanced diets, serious food waste and poor environmental quality. Research has shown that the multiple benefits of an edible campus, which may also be referred to as a school garden or farm catering to various educational levels, can help alleviate the aforementioned problems. However, there is limited research on how to promote the benefits of an edible campus through design. Therefore, taking the South Campus of Hebei University of Technology in China as an example, this paper aims to explore the correlation between design and benefits of an edible campus. The design factors and benefit factors related to an edible campus are extracted through literature search. The design preferences and benefit predictions are obtained through 261 questionnaire surveys and interviews with 30 participants. During the statistical analysis phase, principal component analysis and multiple regression analysis are applied to analyze the correlation between design factors and benefit factors. The results indicate: (1) The design factors of an edible campus can be categorized into seven categories: spatial location, spatial carrier, size, space function, facility configuration, planting and crop varieties, and technology application. (2) The benefits of an edible campus include environmental education, physical and mental health, social interaction, ecological protection, and economic output. (3) There are significant differences in design factors that positively or negatively correlate with different benefits. Among them, the strongest positive correlation exists between planting function and the five benefits, followed by central landscape and container planting. Furthermore, the causes behind the correlation between design factors and benefit factors are analyzed, and design strategies for an edible campus under different benefit orientations are proposed. The findings of this study can contribute to the sustainable development of university campuses in China.

KEYWORDS
edible campus, design, benefit, correlation, strategy

1 Introduction

1.1 Background

1.1.1 Problems faced by Chinese university campuses

From 2013 to 2022, the number of university students in China has increased from 26.475 million to 40.248 million, with an increase of 52%. Generally speaking, a university with 10,000 students consumes approximately 771,000 kg of grain and 384,000 kg of vegetables annually (Liu, 2022). Consequently, Chinese universities, with their rapidly growing population, face a higher food supply demand. Simultaneously, imbalanced dietary habits and food waste pose serious challenges in Chinese universities (Chao et al., 2021). Studies have revealed that 32.62% of Chinese university students have a low intake of vegetables, fruits, beans, milk and drinking water, indicating an imbalanced dietary state (Ding, 2016). And food waste exists in more than 70% of Chinese university campuses, with an average student food waste of about 130 grams per meal, surpassing the urban population's average of 93 grams (Qian et al., 2021). Furthermore, insufficient green spaces within Chinese universities commonly suffer from a lack of diverse landscape types and limited functionality (Ha and Kim, 2021; Liu et al., 2021). This restricts opportunities for students to connect with nature, exercise, and alleviate stress (Yin et al., 2023). Given the challenges of high food demand, imbalanced diet, serious food waste and low-quality campus green space in Chinese universities, it is urgent to explore a comprehensive strategy to alleviate food supply pressure, promote healthy dietary concepts, reduce food waste, enhance green space quality and foster the healthy and orderly development of universities campuses.

1.1.2 A brief overview of related edible campus projects

As an effective approach to addressing issues such as inadequate food supply, imbalanced diets, food waste, and poor environmental quality brought about by campus development, edible campuses have always attracted the attention of researchers. According to the Edible Campus Project at the University of California, an edible campus can be defined as a concept that utilizes campus space for cultivating food, growing crops, and creating opportunities for cooking and education. It may also be known as a school garden or farm, catering to various educational levels.

An edible campus can alleviate high food demand. Roggema (2021) confirmed that the Zernike campus in Groningen can bring 230,000㎡ of production area by using the roof, facade, and ground space for agricultural planting. This can satisfy 100% of the vegetable supply for teachers and students on campus. According to the calculation of Zhang et al. (2018), a vertical farming building covering an area of 5,000㎡ on campus can bring a vegetable production capacity of 1,065,000 kg per year. An edible campus can help improve dietary elements such as fruit and vegetable consumption. Schreinemachers et al. (2020) have indicated that when combined with campus farming and supplementary home farming interventions, student vegetable consumption can increase by 15%–26%, effectively raising the proportion of vegetables in their diet. In addition, Davis et al. (2015) pointed out that an edible campus can promote healthy eating habits through interventions in students' eating behaviours. Furthermore, an edible campus can effectively reduce campus food waste. Torrijos et al. (2021) proposed utilizing edible campus composting facilities to manage campus food residues and produce organic fertilizers, facilitating the recycling of campus organic matter. A study by Erälinna and Szymoniuk (2021) showed that the edible campus at the University of Turku, Finland, can effectively reduce food waste among students by holding food and agriculture education activities. Moreover, an edible campus also improves the quality of campus green space, thus meeting students' recreational and social needs. Cahyanti et al. (2019) highlighted that the edible campus at Universitas Gadjah Mada provides students with opportunities to engage in activities such as touching, observing, thinking, and playing by incorporating multifunctional spaces like compost areas, aeroponic farming area, biogas area, cow farm, recreation area, and composite area. Amiri et al. (2021) demonstrated that students who participate in an edible campus experience significant increases in their love for nature, emotional well-being, stress relief, social skills, and sense of belonging to the campus.

1.1.3 The importance of edible campus design research

Current research on edible campus focuses on its benefit, and design. Benefit research involves a wide range of disciplines and has yielded numerous findings. These include economic benefits, such as crops output (Robinson et al., 2017); health benefits, such as improving physical and psychological conditions (Taylor et al., 2017); ecological benefits, such as biodiversity improvement (Fischer et al., 2019); social benefits, such as promoting social interaction between teachers and students (Laaksoharju et al., 2012); and education benefits, such as imparting agricultural knowledge (Schreinemachers et al., 2017). Research on edible campus design involves integrating agriculture with the campus built environment, such as vertical agriculture (Zhang et al., 2018) and hydroponic roof (Jans-Singh et al., 2020; Ledesma et al., 2020); the design of campus waste recycling systems, such as cafeteria kitchen waste reuse systems and circular food systems (Cahyanti et al., 2019; Erälinna and Szymoniuk, 2021; Torrijos et al., 2021); and multi-subjects collaborative design approach, such as organizing students and medical school patients to collaborate in designing campus garden (Dantas et al., 2018). Generally, design research provides scientific and standardized guidance for the practice of the edible campus, and helps explore new strategies for its construction. Studying the correlation between design and benefits of an edible campus can promote these benefits and enhance the value of such campus through effective design (Nadal et al., 2018). However, there are few studies on the correlation between the design and benefit of an edible campus.

Therefore, this paper firstly obtains the design factors and benefit factors for an edible campus through literature review. On this basis, taking the South Campus of Hebei University of Technology in China as a case study, this paper analyzes the correlation between design factors and benefits of an edible campus, explores the underlying causes, and discusses the future design directions for the edible campus.

2 Materials and methods

2.1 Literature search and screening

In order to ensure the accuracy and completeness of the literature data, a comprehensive search of Chinese and English literature was conducted in this paper. This paper selected China National Knowledge Infrastructure database and Web of Science Core Collection database as literature databases, and then took "edible campus," "edible school," "school garden," "campus garden", "school farm," "campus farm ", "school agriculture," and "campus agriculture" as core words to obtain relevant literatures on edible campus. To mitigate the possibility of overlooking pertinent literature, this paper performed a secondary search on the references cited in the initially retrieved literature. The titles, abstracts, and keywords of these reference papers were scrutinized to determine whether they encompassed the key terms employed in the initial search. Any identified matches were then incorporated into the scope of the literature, ensuring the comprehensiveness of the dataset.

A total of 1,202 literature publications from 1995 to 2023 were selected for further analysis. Steps were taken to narrow the scope of the collected literature: (1) By retaining literature that includes the core word "design" in their titles, abstracts, and keywords, a total of 102 highly relevant articles were obtained. These articles were then classified into 7 categories based on their content: spatial location (5 articles), spatial carrier (5 articles), size (11 articles), space function (33 articles), facility configuration (21 articles), planting and crop varieties (25 articles), and technology application (19 articles). (2) By retaining literature that includes the core word "benefit" in their titles, abstracts, and keywords, a total of 64 highly relevant articles were obtained. These articles were then classified into 5 categories based on their content: economic benefit (16 articles), ecological benefit (7 articles), educational benefit (25 articles), social benefit (16 articles), and health benefit (6 articles). After analyzing the above literature, the edible campus design matrix and edible campus benefit matrix were constructed, as shown in Tables 1, 2.

2.2 Case study

A case study conducts a detailed investigation and analysis of an individual, group, organization, or event in real life, thereby revealing the inner meaning, value, and law of things and forming an in-depth and comprehensive understanding and conclusion on relevant issues (Yin, 2009). Case studies are widely used in edible campus research. For example, Calamidas et al. (2020) used the case of AtlantiCare healthy school in the United States to identify the development challenges faced by an edible campus. Salomão and Reis (2018) elaborated on how the University of São Paulo's Medical School addresses issues such as environmental education and waste management through the implementation of an edible campus. Therefore, this paper used the case study method to provide an in-depth and concrete analysis of the key design factors that affect the benefits of an edible campus.

This paper selected the South Campus of Hebei University of Technology in Tianjin, China as the research case for several reasons: (1) The South Campus of Hebei University of Technology located in Tianjin (Figure 1), which is one of the seven super-large cities in China and at the forefront of economic development. The Tianjin Municipal Government has strong support for edible campus initiatives. As early as 2004, the Tianjin Municipal Government Work Report proposed the development of urban agriculture. The Tianjin Rural Revitalization Comprehensive Promotion Action Plan, issued in 2023, clearly stated the goal of achieving high-quality and efficient development of modern urban agriculture by 2027. (2) The South Campus of Hebei University of Technology is a typical high-density campus with a campus area of 82,300㎡. The *per capita* area of the campus is 27.43㎡/person, which is much lower than the *per capita* standard of 66.6㎡/person stipulated in the campus regulations (MOHURD Ministry of Housing and Urban-Rural Development of the People's Republic of China, 1992) and is also much lower than the *per capita* area of campuses of the same type, which typically exceed 100 square meters per person (Gulwadi et al., 2019). (3) There are already many spontaneous planting activities on the campus, as shown in Figure 2. Additionally, this paper investigated the overall planting intention of this case and found that more than 80% of the respondents expressed a favorable attitude towards planting behavior. This phenomenon indicates that teachers and students have a high degree of acceptance of an edible campus, making it convenient for researching an edible campus.

2.3 Questionnaire survey

Questionnaire surveys can efficiently gather a significant amount of research data within a short timeframe (Patten, 2016), and are widely used in edible campus research. Hazzard et al. (2012) utilized questionnaires to study the reasons behind the development of 216 edible campus projects in California. Similarly, Sottile et al. (2016) employed questionnaire surveys to assess the benefits of fifteen edible campuses in Kenya, Africa. Therefore, this paper adopted a questionnaire survey approach to collect design preferences and benefit predictions from various groups of people on the South Campus of Hebei University of Technology.

The questionnaire in this paper consists of 3 parts: respondent basic information, design preferences, and benefit predictions. The questionnaire includes sixteen items. Except for the respondent basic information section, all other items are measured using a 5-point Likert scale. Options 1 ~ 5 represent strongly disagree to strongly agree (See Supplementary material). The content of the questionnaire mainly refers to the literature search and screening results.

According to Hair's (2009) questionnaire sample size selection theory (Bentler and Chou, 1987; Jackson, 2003), this paper selected 261 teachers and students from the campus as respondents. In order to ensure the survey's representativeness, this study stratified teachers and students from different majors based on population proportions and subsequently conducted simple random sampling of teachers and students from each major (Cochran, 1946). During the stage of simple random sampling, teachers and students from different majors were arranged in a continuous natural number sequence starting from 1. Then, Using excel to generate a random number table. Afterwards, starting from any number on the random number table, this paper took interval readings and selected numbers within the specified range. Numbers outside the range were not selected, and duplicates were avoided until the predetermined sample size was reached. The questionnaires were distributed from September 2022 to November 2022. A total of 261 questionnaires were distributed, resulting in an effective recovery rate of 84.7%. The sample included teachers and students of different ages, genders, education levels, and university majors. The majority of respondents were aged between 18 ~ 30 years old, accounting for 88.2% of the sample. The gender ratio was roughly balanced, and the educational background primarily consisted of graduate and undergraduate degrees. The proportion of teachers and students in the sample aligned with the overall proportion of teachers and students on campus. The study involved participants from 11 different majors, as shown in Table 3.

2.4 Interview

After the questionnaire survey, we conducted interviews. Firstly, we employed snowball sampling to acquire the interview sample

TABLE 1 Design factor matrix of an edible campus based on literature review.

Level 1	Level 2	Level 3	Indicator interpretation	References
Inner space organization	Size	Micro size space	Less than 100 ㎡	Ding (2020)
		Small size space	100 ~ 500 ㎡	
		Medium size space	500 ~ 1,000 ㎡	
		Large size space	More than 1,000 ㎡	
	Space function	Planting function	Functional spaces that accommodate the processes of breeding, sowing, nurturing, and harvesting crops	Guitart et al. (2014)
		Cooking function	—	Saeumel et al. (2019)
		Learning function		LaCharite (2016)
		Farming function		Cahyanti et al. (2019)
		Resource recycling function		
		Energy Production		
		Recreation function		Danks (2010)
		Socializing function		
	Facility configuration	Planting and maintaining facilities	Planting beds, greenhouses, tool sheds, composting facilities, irrigation facilities, sheep pens, chicken coops, beehives	Bucklin-Sporer and Pringle (2010)
		Safety facilities	Gate, railing, fire alarm device, roof fencing device, intelligent security monitoring system, switch room, barrier-free facilities	Goodyear et al. (2016)
		Entertainment service facilities	Artificial hillside, sand, pond, graffiti wall, stage, pavilion, seat, toilet, kitchen	Danks (2010)
		Educational facilities	Signs, billboards, simple outdoor classrooms	Bucklin-Sporer and Pringle (2010)
		Resource recycling facilities	Rainwater collection facilities, water circulation and treatment facilities, photovoltaic panels, wind turbines, biogas digesters	Wei et al. (2019) and Yang et al. (2016)
	Planting and crop varieties	Fruit tree	—	Sen et al. (2022)
		Vegetable		
		Grain		
		Flower		Goodyear et al. (2016)
		Herb		Dantas et al. (2018)
		Sheep and poultry		Danks (2010)
		Fish and Shrimp		
		Aquatic crops		
	Technology application	Compost	—	Chandra and Diehl (2019)
		Aquaponics	A mutually beneficial symbiotic ecosystem combining aquaculture and hydroponic cultivation.	Trombadore et al. (2019)
		Hydroponics	The cultivation method that directly infiltrating the roots of plants into nutrient solution to provide plants with the substances needed for growth.	Zhang et al. (2018)
		Aeroponics	The cultivation method that suspending the root system in the air and spraying the nutrient solution to the root surface at a certain frequency.	
		Soil cultivation	—	Danks (2010)
		Greenhouse	—	Jans-Singh et al. (2021)
		Container planting	Flower pot, foam box, etc.	Dantas et al. (2018)
		Facade planting	—	Xie (2018)
		Reclaimed water cycle	The process of treating domestic sewage and rainwater as non-referenced water that meets a certain water quality standard for irrigation, clean and other uses.	Wei et al. (2019)
		Rainwater collecting	—	

(Continued)

TABLE 1 (Continued)

Level 1	Level 2	Level 3	Indicator interpretation	References
External site selection	Spatial location (the specific construction site of an edible campus)	Public teaching area	Teaching building, library, engineering training centre	He (2010)
		Academy teaching area	Academy building	
		Logistics office area	Administrative office building, financial building, etc.	Song and Zhou (2006)
		Residential area	Dormitory buildings, canteens, student activity centres, teachers' apartments, etc.	He (2010)
		Sports activities area	Stadiums, gymnasiums, Aquatics Centre, etc.	
	Spatial carrier (the specific built environment elements integrating with agriculture)	Central landscape	The landscape located in important spatial areas such as the central axis and central zones of the campus	Tu (2007)
		Boundary landscape	The landscape around the boundary such as the campus wall	
		Building complex landscape	The landscape surrounded by different buildings on campus	
		Building courtyard landscape	The landscape enclosed by buildings	
		Road landscape	The landscape on both sides and above the road	
		Square landscape	The square landscape before the primary and secondary entrance of the campus	
		Marker landscape	Landscape around monuments, sculpture, and other markers	
		Carriageway	—	He (2006)
		Pedestrian road		
		Car park		
		Building roof		Tu (2007)
		Building facade		

(Lopes et al., 1996; Mason, 2010). We established contact with school leaders and counselors responsible for teacher and student management, and identified two initial respondents from each of the teachers and student groups involved in the questionnaire survey through them. Four respondents had participated in campus agricultural planting activities. Subsequently, the initial participants were asked to provide names of teachers or students who had also taken part in the questionnaire survey and possessed experience in campus agricultural cultivation. Through a process of screening and exclusion, a total of 30 individuals participated in this interview. Each respondent was interviewed for 30 ~ 60 min. Twenty-five respondents were interviewed face-to-face, while five participated in online Tencent meetings. The interviews were conducted from October 2022 to December 2022. The interview content focused on the reasons for choosing different edible campus benefits. During the interviews, the respondents' responses were recorded and coded according to the category of open questions.

2.5 Statistical analysis

SPSS is easy to operate and can provide reliable results. It is a common analysis software for quantitative analysis in the field of edible campus research (Somerset and Bossard, 2009; Burt et al., 2018; Hoover et al., 2021). This paper used SPSS. V26 software to process and analyze the edible campus questionnaire and interview data. The data in all the operation steps showed statistical significance with $p < 0.05$ (Gigerenzer, 1989). The flowchart is shown in Figure 3.

The first step was to verify the reliability and validity of the sample. In this paper, the 16 items of the questionnaires were tested for reliability and validity. The resulting Cronbach's alpha was 0.963 (>0.7), which indicated good reliability of the sample (Gliem and Gliem, 2003). The KMO value was 0.855 (>0.7), and Bartlett's spherical test showed $p < 0.05$, which was suitable for exploratory factor analysis (Durdyev and Mbachu, 2018).

The second step was to conduct descriptive analysis. The number and percentage of individuals who chose Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree for each item related to design preference and benefit prediction in the questionnaire were counted. This was done to demonstrate the recognition of teachers and students towards various design and benefit factors for an edible campus.

The third step was to carry out exploratory factor analysis. Factor analysis is a method to rearrange the original variables to form multiple simplified hypothetical variables based on the correlation of the original variables (Ding et al., 2020). Exploratory factor analysis can generate an optimal factor structure scale through multivariate analysis procedures. When the test results met the requirements of factor analysis, this paper used the principal component analysis method and the maximum variance method to extract common factors for 25 edible campus benefit indicators. The standard for selecting common factors was (Peterson, 2000): (1) The characteristic root was greater than or equal to 1. (2) The absolute value of the factor loading was greater than 0.40. This standard can eliminate the influence caused by low factor loading and crossover of measurement items.

TABLE 2 Benefit factor matrix of an edible campus based on literature review.

Level 1	Level 2	References
Economic benefit	Agricultural product supply	Souter-Brown et al. (2021)
	Providing jobs	Ferguson et al. (2019)
	Business operations and sales	
	Reducing canteen procurement	Wells et al. (2018)
	Reducing energy use	Yang et al. (2016)
Ecological benefit	Biodiversity improvement	Mnisi et al. (2021)
	Material cycle	Vazquez et al. (2020)
	Reducing carbon emissions	Sen et al. (2022)
	Efficient utilization of water resources	Attwater et al. (2016)
	Relieving campus microclimate and indoor thermal environment	Kim et al. (2020)
Educational benefit	Agricultural education	Cramer et al. (2019)
	Labor education	Yao and Kang (2022)
	Deepening the understanding of food and vegetables	Leuven et al. (2018)
	Promoting green low-carbon lifestyle	Wang (2013)
	Increasing the love of local fruits and vegetables for teachers and students	Taniguchi and Akamatsu (2011)
Social benefit	Enhancing personal interaction ability	Jakubec et al. (2021)
	Building public service awareness	
	Promoting teacher-student communication between different grades and disciplines	Kim et al. (2014)
	Getting friends	
	Improving interpersonal relationships	
Health benefit	Enhancing physical fitness	Utter et al. (2016)
	Promoting dietary health	
	Pressure release	Chawla et al. (2014)
	Emotional stability	
	Psychological resilience enhancement	Oh et al. (2020)

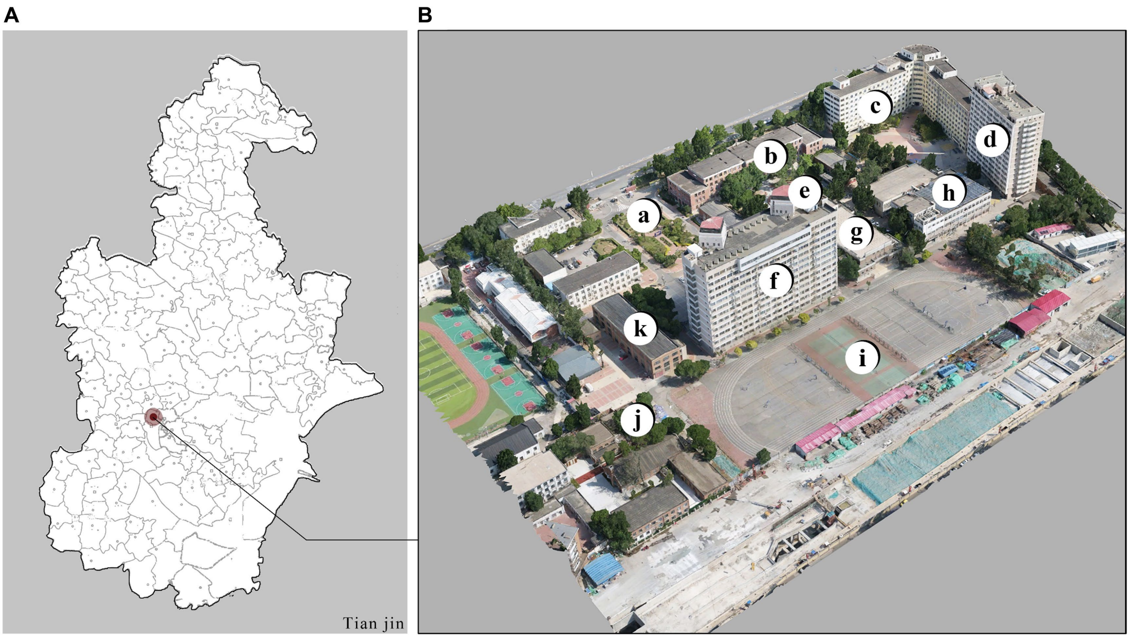

FIGURE 1
Campus location [**(A)** Macro location of campus. **(B)** Campus 3D model (a) Entrance garden (b) Academy building (c) Male dormitory building (d) Female dormitory building (e) Cedar square (f) Teaching building (g) Auditorium (h) Canteen (i) Stadium (j) Laboratory building (k) Engineering training center].

FIGURE 2
Campus agricultural planting. [**(A)** Hawthorn tree. **(B)** Vegetable garden 1. **(C)** Vegetable garden 2. **(D)** Window planting. **(E)** Indoor planting. **(F)** Pumpkin planting. **(G)** Vegetable garden 3. **(H)** Planting box. **(I)** Loofah].

The fourth step was to perform multiple linear regression analysis. Multiple linear regression analysis is a method that regards one of the related variables as a dependent variable and the other variables as independent variables, and establishes a linear quantitative relationship (Mark and Goldberg, 1988). Before conducting multiple linear regression analysis, it should be determined that there is no multicollinearity for the variance inflation factors (VIF) associated with the independent variable and the judgment standard is VIF<10. The VIF results of this paper were between 2.776 and 6.844, which suggested there was no multicollinearity problem. Therefore, this paper took the edible campus design indicators as independent variables and the edible campus benefit common factors obtained by factor analysis as dependent variables. Then, it conducted multiple linear regression analysis and built an edible campus design decision-making model for benefit promotion.

3 Results

3.1 Design and benefit factors of an edible campus

3.1.1 Research on the design factors of an edible campus

We obtained 102 papers through literature search and screening. Based on in-depth reading and analysis, we extracted entries related to edible campus design and categorized them for summarization. And then, we grouped and classified entries with similar meanings. Finally, we found that existing research on edible campus design focuses on five aspects: size, space function, facility configuration, planting and crop varieties, and technology application. Furthermore, based on the literature reviewed, we subdivided the design factors for each aspect and constructed a design factor matrix, as shown in Table 1.

Firstly, the size of an edible campus. The minimum construction area of an edible campus at the University of Turku in Finland is 10×10㎡ (Erälinna and Szymoniuk, 2021). And the minimum area of an edible campus in Italy is 4×4㎡ (Pulighe and Lupia, 2016). Conversely, the minimum area of an edible rooftop is generally 50㎡ (Ledesma et al., 2020). Royer et al. (2023) pointed out that if the planting space is too small, urban agriculture will exhibit fragmented characteristics. By combining the above research with the size classification used in Chinese community garden research, this paper divided edible campus sizes into four types: less than 100 m^2, $100 \sim 500\ m^2$, $500 \sim 1{,}000\ m^2$, and greater than 1,000 m^2 (Ding, 2020). Secondly, the space function of an edible campus. Typically, planting (Guitart et al., 2014), cooking (Saeumel et al., 2019), learning (LaCharite, 2016), socializing, and recreation (Danks, 2010) are essential functions of an edible campus. The design of the edible campus at Universitas Gadjah Mada also included functions such as animal farming and resource recycling, while incorporating photovoltaic panels for energy production to sustain the campus

TABLE 3 Interview sample personnel composition.

Item		Number of sample personnel	Number of campus personnel
Age	18 or less	13 (5.88%)	185 (6.17%)
	18 ~ 30	195 (88.24%)	2,650 (88.33%)
	31 ~ 40	7 (3.17%)	90 (3.00%)
	41 ~ 50	5 (2.26%)	60 (2.00%)
	51 ~ 60	1(0.45%)	15 (0.50%)
Gender	Men	130 (58.82%)	1760 (58.67%)
	Female	91 (41.18%)	1,240 (41.33%)
Educational background	Postgraduate	96 (43.44%)	1,300 (43.33%)
	Undergraduate	125 (56.56%)	1700 (56.67%)
Identity	Student	209 (94.57%)	2,865 (95.50%)
	Teacher	12 (5.43%)	135 (4.50%)
University major category	Water and wastewater science and engineering	7 (3.17%)	90 (3.00%)
	Urban and rural planning	6 (2.71%)	80 (2.67%)
	Electronic science and technology	20 (9.05%)	270 (9.00%)
	Engineering management	1 (0.45%)	25 (0.83%)
	Industrial design	7 (3.17%)	95 (3.17%)
	Mechanical engineering	25 (11.31%)	350 (11.67%)
	Architecture	139 (63.90%)	1800 (60.00%)
	Mechanics	2 (0.90%)	35 (1.17%)
	Civil engineering	1 (0.45%)	25 (0.83%)
	Science of literature	1 (0.45%)	25 (0.83%)
	Art design	12 (5.43%)	205 (6.83%)

(Cahyanti et al., 2019). Thirdly, the facility configuration of an edible campus. Planting and maintaining facilities are the foundational infrastructure that an edible campus must have in place. These facilities encompass planting beds, composting facilities, tool sheds, and irrigation systems (Bucklin-Sporer and Pringle, 2010). Goodyear et al. (2016) recommended the installation of protective nets and fences around edible campuses to prevent wildlife interference with agricultural activities on campus. Bucklin-Sporer and Pringle (2010) argued that installing educational facilities such as outdoor blackboards and entertainment service facilities such as tree stumps, hay bales, and display walls in edible campuses can create a rich variety of activities. Wei et al. (2019) proposed that setting up rainwater collection facilities such as sunken floors and small reserved reservoirs, as well as resource recycling facilities like rooftop photovoltaic panels, in edible campuses can reduce surface runoff and achieve resource recycling. However, Ghosh (2023) pointed out that photovoltaic equipment may have drawbacks in preventing light penetration and hindering crop growth. Fourthly, the planting and crop varieties of an edible campus. Crops are essential for an edible campus, such as fruit trees, vegetables, grains, etc. (Sen et al., 2022). Additionally, flowers planting (Goodyear et al., 2016), herb planting (Dantas et al., 2018), poultry farming and livestock farming (Danks, 2010) are common agricultural activities among Dalhousie University School of Agriculture, Saint Paul University School of medicine, and other American edible campuses. Conversely, Pradhan et al. (2023) expressed concerns about poultry farming and livestock farming, pointing out that improper management of livestock manure can lead to potential risks of zoonotic pathogen contamination. Fifthly, the technology application of an edible campus. Compost (Chandra and Diehl, 2019), soil cultivation (Danks, 2010), aquaponics (Trombadore et al., 2019), greenhouse (Jans-Singh et al., 2021) and container planting (Dantas et al., 2018) are common agricultural technologies in an edible campus. Zhang et al. (2018) proposed the application of hydroponics and aeroponics for vertical farming in an edible campus. However, Pradhan et al. (2023) questioned the use of technologies such as hydroponics and aeroponics, believing that these applications not only consume a large amount of water and energy but also affect production by increasing the risk of diseases. Wei et al. (2019) suggested using rainwater collection and reclaimed water cycle technology in school roof gardens. Januszkiewicz and Jarmusz (2017) proposed a method of facade planting technology using building facades for an edible campus. In contrast, Aggarwal et al. (2024) pointed out the high costs associated with facade planting but also proposed a solution strategy to improve investment returns by developing high-yield, space-efficient crop varieties.

Considering the particularity of Chinese university campuses, this paper extracted elements of campus space design based on the review of existing literature. Chinese university campuses generally encompass public teaching area, academy teaching area, sports activities area, residential area, and logistics office area (Song and Zhou, 2006; He, 2010). The built environment elements on the campus include buildings, landscapes, and roads, which can be further subdivided into building systems (such as building facade and building roof), landscape systems (encompassing central landscape, boundary landscape, building complex landscape, building courtyard landscape, road landscape, square landscape, and marker landscape) (Tu, 2007), and road systems (including carriageway, pedestrian road, and car park) (He, 2006).

Based on the above elements, this paper establishes an edible campus design matrix, as shown in Table 1. Among them, spatial location refers to the specific construction site of an edible campus, and spatial carrier refers to the specific built environment elements integrating with agriculture. This matrix includes three levels of design factors, with a total of 52 design indicators at the third level. The indicator interpretation is the analysis and explanation of the third level indicators.

3.1.2 Research on the benefit factors of an edible campus

According to the research process outlined in section 3.1.1, we divided the benefits of an edible campus into 5 categories: economic benefit, ecological benefit, educational benefit, social benefit and health benefit. An edible campus can bring direct economic benefits such as agricultural product supply (Chaparro et al., 2009), as well as additional economic value by providing jobs, increasing opportunities for business operations, and driving sales (Ferguson

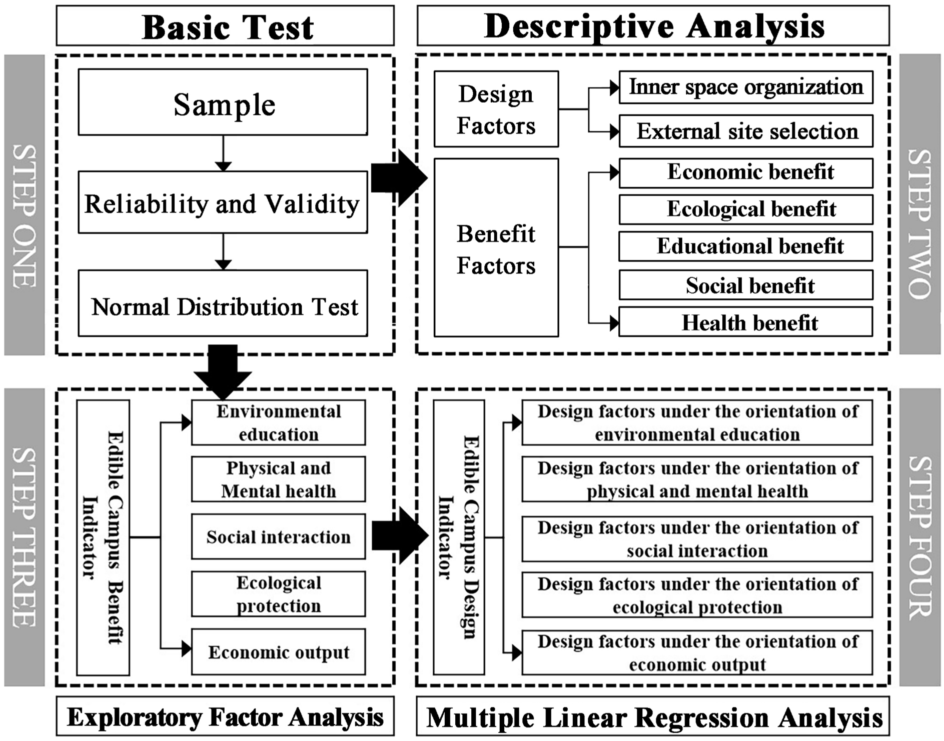

FIGURE 3
Flowchart of statistical analysis.

et al., 2019). Based on research on the commercial value and return on investment of an edible campus in Phoenix, Zhang et al. (2018) predicted the commercial value and return on investment of vertical agriculture in 24 canteens at Huazhong University of Science and Technology, suggesting that edible campuses can reduce cafeteria procurement costs and achieve an annual profit of $92,000 after reaching breakeven. Wells et al. (2018) showed that the combination of an edible campus and school kitchens can help low-income families relieve food stress. Yang et al. (2016) believed that the integration of campus roof agriculture and photovoltaic panels can reduce energy funding investment. An edible campus can also help improve biodiversity and the utilization of water resources (Attwater et al., 2016; Mnisi et al., 2021). Vazquez et al. (2020) confirmed that composting and reusing organic waste in an edible campus can achieve the purpose of material recycling. Ledesma et al. (2022) found that thermally integrated rooftop greenhouses (iRTG) can reduce classroom heat load by 42%. Kim et al. (2020) highlighted the positive contributions of an edible campus roof project at Seoul National University in relieving the campus microclimate and indoor thermal environment. The education benefit brought by an edible campus is considered very important (Turner et al., 2016; Cramer et al., 2019). The research of Leuven et al. (2018) showed that edible campuses have led to a 26% increase in students' accurate knowledge regarding the importance of consuming more vegetables. A study by Taniguchi and Akamatsu (2011) confirmed that the Japanese Edible Campus Program can increase the appreciation for local fruits and vegetables among teachers and students. Wang (2013) demonstrated that campus roof agriculture can promote a green, low-carbon lifestyle. An edible campus enhances public service awareness and personal interaction ability (Jakubec et al., 2021). Kim et al. (2014) found that an edible campus can improve interpersonal relationships and increase the likelihood of making friends. Moreover, Utter et al. (2016) confirmed that adolescents who participated in an edible campus had better physical fitness and a healthier diet. Research by Chawla et al. (2014) showed that participation in an edible campus can help stabilize emotions, release stress, and enhance psychological resilience, thereby improving mental health.

Based on the above research contents, this paper establishes an edible campus benefit matrix, as shown in Table 2. This matrix includes 2 levels of benefit indicators with a total of 25 benefit indicators.

3.2 Descriptive analysis

As shown in Figure 4, the clustering of the sample's edible campus design preferences is evident. Among the 52 edible campus design indicators, 36 design indicators were recognized by more than half of the respondents (Figure 4). This paper recorded the number of respondents who chose "agree" and "strongly agree" for each design indicator. The results showed that 79.6% of the respondents agreed to have an edible campus in the residential area. Boundary landscape, building courtyard landscape, pedestrian roads, car parks, and building roofs are popular spaces for edible campus construction. 50% of respondents preferred small-sized spaces. 80% of the respondents favored planting, recreation, socializing functions. More than 80% of the respondents considered planting and maintenance, safety, and resource recycling facilities to

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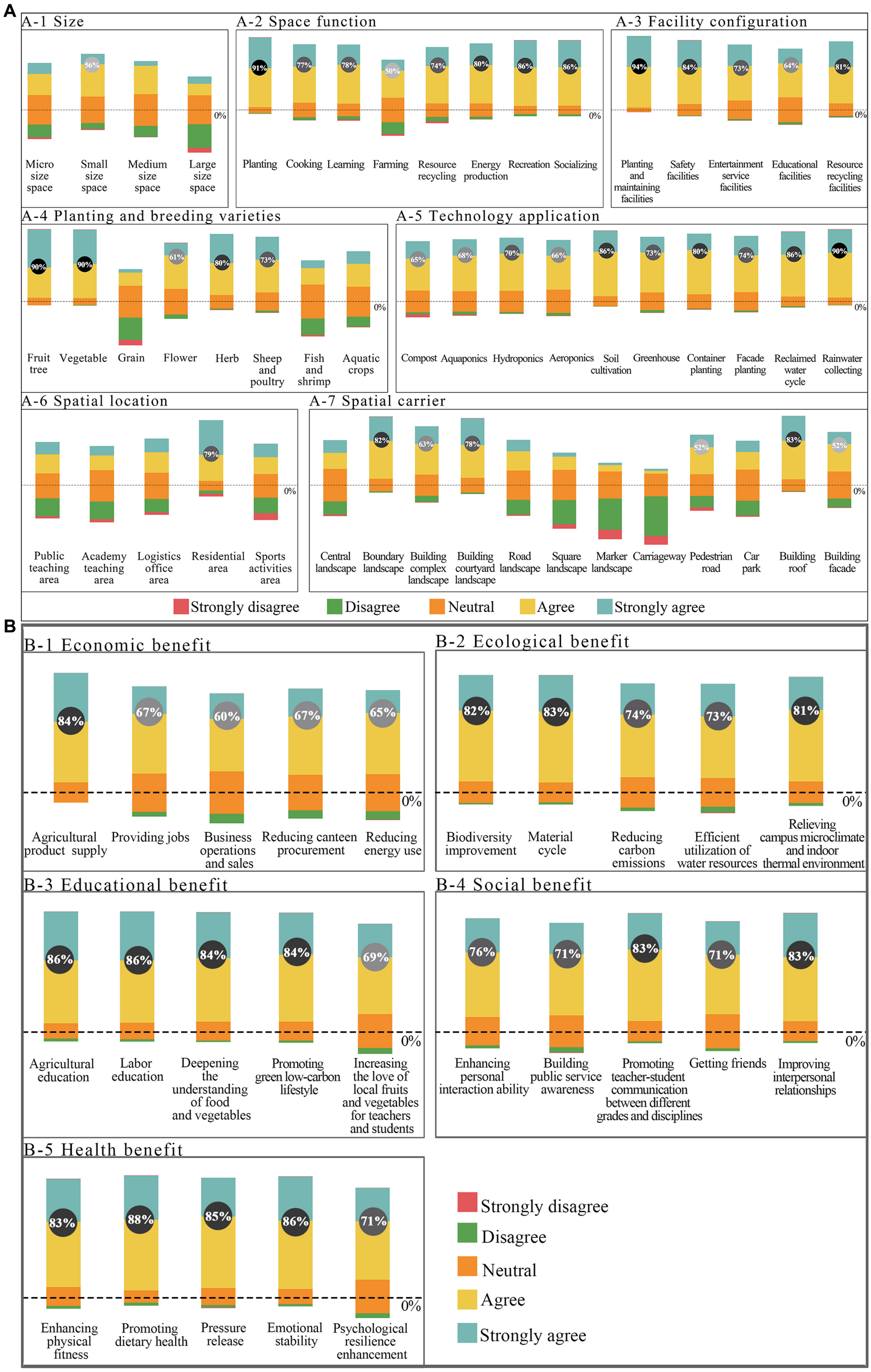

FIGURE 4
Descriptive analysis of the design and benefits of an edible campus. [**(A)** Descriptive analysis of design factors. **(B)** Descriptive analysis of benefit factors]. We use a diverging bar chart centered around "Neutral" to present the selection results of design indicators and benefit indicators for an edible campus. The five colors represent the options: Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. The size of each bar represents the proportion of individuals who selected that option out of the total number of respondents. The baseline (0%) is located at the center of the "neutral" option result. By comparing the sizes of the upper and lower bar charts relative to the baseline (0%), we can intuitively observe the difference in the

(Continued)

FIGURE 4 (Continued)

number of people who choose to agree and disagree. We use a circle plus percentage format to identify the design indicators and benefit indicators that are recognized by more than half of the respondents. The percentage value represents the proportion of people who choose "Agree" and "Strongly Agree." The circle changes gradually in color from grey to black. The darker the color, the higher the proportion of people who choose "agree" and "strongly agree".

TABLE 4 Rotated factor analysis result on the benefit indicators of an edible campus.

Rotated factor matrix					
Benefit indicators	Rotated factors				
	Environmental education	Physical and mental health	Social interaction	Ecological protection	Economic output
Labor education	0.783				
Agricultural education	0.772				
Deepening the understanding of food and vegetables	0.751				
Promoting green low-carbon lifestyle	0.712				
Increasing the love of local fruits and vegetables for teachers and students	0.515				
Pressure release		0.799			
Emotional stability		0.796			
Psychological resilience enhancement		0.783			
Enhancing physical fitness		0.749			
Improving interpersonal relationships			0.832		
Enhancing personal interaction ability			0.785		
Getting friends			0.775		
Promoting teacher-student communication between different grades and disciplines			0.620		
Efficient utilization of water resources				0.802	
Reducing energy use				0.790	
Reducing carbon emissions				0.739	
Relieving campus microclimate and indoor thermal environment				0.646	
Providing jobs					0.855
Business operations and sales					0.756
Agricultural product supply					0.466

Extraction method: principal component analysis. Rotation method: Kaiser normalized maximum variance method. a. The rotation has converged after 7 iterations.

be essential. Regarding planting and crop varieties, more than 70% of the respondents chose fruit trees, vegetables, grains, flowers, as well as sheep and poultry. As for technology application, over 80% of the respondents selected soil cultivation, reclaimed water cycle, and rainwater collecting technology.

As shown in Figure 4, most teachers and students agreed with the educational, health, and ecological benefits of an edible campus, while questioning the economic and social benefits. More than 80% of the respondents selected agricultural product supply, agricultural education, labor education, psychological resilience enhancement, emotional stability, biodiversity improvement, material cycling, etc. However, for benefits such as business operations and sales, improving interpersonal relationships, increasing the appreciation of local fruits and vegetables among teachers and students, providing jobs, and reducing canteen procurement costs, less than 60% of the respondents selected "agree" and "strongly agree".

3.3 Correlation analysis

This paper conducted factor analysis on 25 benefit indicators and extracted 5 common factors. The cumulative variance contribution rate of the common factors was 70.6%. According to the meanings of the common factors, the 5 common factors were named as environmental education, physical and mental health, social interaction, ecological protection, and economic output (Table 4).

The level 3 design indicators from the edible campus design matrix were selected as independent variables, and 5 types of edible campus benefits, including environmental education, physical and mental health, social interaction, ecological protection, and economic output, were chosen as dependent variables. Then, the multiple linear regression analysis for edible campus benefits and design indicators was carried out. The results are as follows:

When the dependent variable was environmental education, 9 design indicators with a high correlation were identified, of which 6 indicators were positively correlated with environmental education, and 3 indicators were negatively correlated. These 9 design indicators covered 6 design elements, namely spatial location, spatial carrier, size, space function, facility configuration, and technology application. The design indicators that exhibited a positive correlation were learning, safety facilities, residential area, container planting, large size space, and building roof. On the other hand, the negatively correlated design indicators were entertainment service facilities, sports activities area, and academy teaching area (Table 5).

When the dependent variable was physical and mental health, 9 design indicators with a high correlation were recognized, of which 6 indicators were positively correlated with environmental education, and 3 indicators were negatively correlated. These 9 design indicators covered 6 design elements, namely spatial location, spatial carrier, space function, facility configuration, planting and crop varieties, and technology application. The design indicators that presented a positive correlation were soil cultivation, compost, educational facilities, sheep and poultry, planting, and central landscape. On the other hand, the negatively correlated design indicators were energy production, public teaching area, and aquatic crops (Table 6).

When the dependent variable was social interaction, 4 design indicators with a high correlation were determined, of which 3 indicators were positively correlated with social interaction, and 1 indicator was negatively correlated. These 4 design indicators covered 3 design elements, namely space function, facility configuration, and technology application. The design indicators that displayed a positive correlation were facade planting, entertainment service facilities, and socializing. On the other hand, the negatively correlated design indicator was container planting (Table 7).

When the dependent variable was ecological protection, 11 design indicators with high correlation were identified, of which 8 indicators were positively correlated with ecological protection, and 3 indicators were negatively correlated. These 11 design indicators covered 6 design elements, namely spatial carrier, size, space function, facility configuration, planting and crop varieties, and technology application. The design indicators that showed a positive correlation were hydroponics, central landscape, small size space, aquatic crops, aquaponics, resource recycling facilities, container planting, and fruit tree. On the other hand, the negatively correlated design indicators were grain, flower, and planting (Table 8).

When the dependent variable was economic output, 5 design indicators with a high correlation were recognized, of which 4 indicators were positively correlated with economic output, and 1 indicator was negatively correlated. These 5 design indicators covered 3 design elements, namely spatial carrier, planting and crop varieties, and space function. The design indicators that presented a positive correlation were central landscape, flower, herb, and planting. On the other hand, the negatively correlated design indicator was pedestrian road (Table 9).

Overall, among the 52 design indicators, a total of 29 indicators exhibited significant correlations with 5 common benefit factors of an

TABLE 5 Regression analysis results between environmental education and design factors.

Factors set		Standardization coefficient beta	*t*	Significance
9	Constant		−5.080	0.000
	Learning	0.309	4.865	0.000
	Safety facilities	0.225	3.456	0.001
	Residential area	0.211	3.106	0.002
	Container planting	0.141	2.266	0.025
	Large size space	0.143	2.319	0.021
	Entertainment service facilities	−0.130	−1.993	0.048
	Sports activities area	−0.127	−1.826	0.049
	Academy teaching area	−0.140	−2.100	0.037
	Building roof	0.138	2.098	0.037

TABLE 6 Regression analysis results between physical and mental health and design factors.

Factors set		Standardization coefficient beta	*t*	Significance
9	Constant		−5.345	0.000
	Soil cultivation	0.219	3.250	0.001
	Compost	0.160	2.259	0.025
	Educational facilities	0.188	2.861	0.005
	Sheep and poultry	0.194	2.867	0.005
	Energy production	−0.171	−2.537	0.012
	Planting	0.181	2.519	0.013
	Public teaching area	−0.163	−2.523	0.012
	Central landscape	0.184	2.768	0.006
	Aquatic crops	−0.148	−2.052	0.041

TABLE 7 Regression analysis results between social interaction and design factors.

Factors set		Standardization coefficient beta	*t*	Significance
4	Constant		−5.199	0.000
	Entertainment service facilities	0.250	3.667	0.000
	Facade planting	0.266	3.770	0.000
	Socializing	0.123	1.783	0.046
	Container planting	−0.123	−1.789	0.045

TABLE 8 Regression analysis results between ecological protection and design factors.

Factors set		Standardization coefficient beta	*t*	Significance
11	Constant		−4.734	0.000
	Hydroponics	0.216	3.195	0.002
	Central landscape	0.215	3.241	0.001
	Large size space	0.174	2.829	0.005
	Aquatic crops	0.162	2.469	0.014
	Grain	−0.232	−3.660	0.000
	Aquaponics	0.175	2.471	0.014
	Planting	−0.191	−2.893	0.004
	Resource recycling facilities	0.166	2.646	0.009
	Flower	−0.175	−2.769	0.006
	Container planting	0.146	2.317	0.022
	Fruit tree	0.152	2.302	0.022

TABLE 9 Regression analysis results between economic output and design factors.

Factors set		Standardization coefficient beta	*t*	Significance
5	Constant		−5.131	0.000
	Central landscape	0.211	3.297	0.001
	Herb	0.167	2.620	0.009
	Flower	0.158	2.453	0.015
	Planting	0.146	2.266	0.024
	Pedestrian road	−0.105	−1.664	0.048

edible campus. Other design indicators with no significant correlation were logistics office area, boundary landscape, building complex landscape, building courtyard landscape, road landscape, square landscape, marker landscape, carriageway, car park, building façade, micro size space, medium size space, cooking, farming, resource recycling, recreation, planting and maintaining facilities, vegetables, fish and shrimp, aeroponics, greenhouse, reclaimed water cycle, and rainwater collecting.

4 Discussion

4.1 The correlation mechanism between design and benefit of an edible campus

4.1.1 Environmental education benefit and design factors

Regarding spatial location, the residential area serves as the space where students engage in outdoor activities most frequently. Conducting a series of edible campus activities such as planting, maintenance, harvesting, and cooking in this area easily attracts more participants, thereby spreading the concept of labour education and agriculture education and achieving the effect of environmental education. On the other hand, the sports activities area belongs to the active zone, and the shouts and cheers generated by the sports activities can interfere with the edible campus education activities. Similarly, the noise from the large-scale model tool room and mechanics laboratory located in the academy teaching area of the South Campus of Hebei University of Technology will also affect the education activities of an edible campus. Therefore, the sports activities area and academy teaching area were negatively correlated with environmental education benefits. Student A said: "We often conduct mechanical and material experiments in the civil engineering academy, which will generate a lot of noise and affect the effect of an edible campus environmental education".

With respect to spatial carrier, the building roof is a relatively independent space and is less disturbed by the external environment. By utilizing the building roof for various farming experiences, agricultural education, and other edible campus activities, participants can fully immerse themselves in these activities with their mind and body, thereby enhancing the educational significance of an edible campus. Student B said: "Roof space is very independent and quiet. And the transformed edible campus roof also offers pleasant scenery. If I take part in educational activities on the building roof, I will feel relaxed, fan and focused".

As for size, the larger the construction area of an edible campus, the more planting and crop varieties and technology application it can have (Yang et al., 2016). A variety of grains, flowers, herbs, farming animals, and new technologies can provide students with more agricultural knowledge, breeding knowledge, and scientific knowledge. Therefore, the environmental education benefits of an edible campus in a large-sized space are better.

Regarding space function, when the configuration ratio of learning function is higher, the environmental education benefits will be better (Amiri et al., 2021).

With regard to facility configuration, a safe edible campus space is the prerequisite for ensuring the normal development of educational activities (Bucklin-Sporer and Pringle, 2010). Therefore, having proper safety facilities can promote the education function. Student C said: "During environmental education activities, we will carry out fruit and vegetable picking, processing, and cooking, and we need safety facilities to avoid possible accidental ingestion, water and electricity hazards." On the other hand, entertainment service facilities can lead to excessive entertainment activities, thereby interfering with educational activities and negatively impacting environmental education. Student D said: "If you play and learn at the same time in an edible campus, neither of them can achieve good results".

In terms of technology application, container planting is easy to operate and display, making it a convenient tool for promoting and popularizing edible campus education activities. Therefore, container planting can effectively promote environmental education.

4.1.2 Physical and mental health benefit and design factors

As for spatial location, Stepansky et al. (2022) pointed out that long-term participation in planting activities and social activities is a necessary condition for cultivating participants' physical and mental health in an edible campus. However, the mobility of teachers and students in the public teaching area is relatively high, making it difficult to ensure their participation in an edible campus. Therefore, public teaching areas are negatively correlated with physical and mental health. Teacher A said: "Teachers and students who go to the public teaching area spend most of their time in class and have no time to participate in an edible campus, thus it is difficult to improve their physical and mental health".

Regarding spatial carrier, a larger central landscape area can extend the duration of participants engaging in farming activities and exercising their bodies (Liu et al., 2018). At the same time, combining the productive landscape with the ornamental landscape in the central landscape can enhance the healing effect. Therefore, the central landscape can promote physical and mental health.

With regard to space function, more planting function can provide more opportunities for teachers and students to exercise (Oh et al., 2020). While, the energy production function based on photovoltaic panels and wind turbine may bring noise (Wang et al., 2014), waste water, waste gas and soil pollution detrimental to the health of the participants (Qi and Zhang, 2017), therefore energy production function is negatively correlated with physical and mental health benefits.

Regarding facility configuration, an edible campus equipped with educational facilities such as informational boards promoting a balanced diet and outdoor classrooms for teaching therapeutic knowledge, can assist teachers and students in developing a proper understanding of dietary concepts (Bhatt et al., 2008). It can also guide them to connect with nature, and achieve emotional stability and stress release. Therefore, there is a positive correlation.

With respect to planting and crop varieties, feeding, stroking, and cleaning animals can effectively relieve personal stress, loneliness, and anxiety, thereby improving mental health (Grajfoner et al., 2021). Therefore, raising sheep and poultry in an edible campus can promote physical and mental health. However, aquatic crops are more likely to attract mosquitoes, fleas, and flies than land crops, which can endanger the health of teachers and students (Luo et al., 2014). Thus, it can negatively impact physical and mental health benefits. Student E said, "My hometown is a paddy field planting area, and during the summer, there are a lot of mosquitoes attracted to aquatic plants, which can bite people".

In terms of technology application, respondents generally believed that traditional and well-known growing techniques, such as soil cultivation and compost, are more beneficial to the health of teachers and students, although related studies confirmed the opposite (Catanzaro and Ekanem, 2004). Student F said, "I lived in the countryside when I was a child. I think that using soil and compost can grow greener and healthier agricultural products, which will bring better physical and mental health effects".

4.1.3 Social interaction benefit and design factors

Regarding space function, increasing the proportion of socializing functions can promote communication activities between teachers and students (Corbolino et al., 2020), which in turn promotes social interaction.

With respect to facility configuration, entertainment service facilities, such as stage and kitchen, not only provide social places for teachers and students but also attract more teachers and students to exchange (Danks, 2010). Therefore, entertainment service facilities can promote social interaction.

As for technology application, facade planting can increase the aesthetics of an edible campus and provide some shading, which helps attract teachers and students to gather and communicate, so the facade planting can promote social interaction. Generally, container planting can be mastered and completed by a single person, which reduces the likelihood of teachers and students gathering and interacting, so container planting is negatively correlated.

4.1.4 Ecological protection benefit and design factors

Regarding spatial carrier, it has been found that large landscape areas favour plant and animal migrations, resulting in higher biodiversity (Han and Keeffe, 2021). Thus, building an edible campus in a central landscape can increase species richness, since central landscapes are usually larger in size. Therefore, central landscapes are beneficial to the ecological protection of an edible campus.

With respect to size, constructing an edible campus in a large space can increase the green area, thereby connecting fragmented landscapes in the campus and facilitating the migration of animals and plants (Ioja et al., 2014). Therefore, a large-sized space can promote the ecological protection of an edible campus.

As for space function, excess planting function may increase the input of fertilizer and the use of mechanical equipment, both of which can result in higher greenhouse gas emissions (Liang et al., 2021). These behaviours can negatively impact the ecological effect of an edible campus. Therefore, there is a negative correlation between planting function and ecological protection.

Regarding facility configuration, resource recycling facilities, such as water circulation and waste recycling, can alleviate the burden on the ecological environment (Cahyanti et al., 2019). Therefore, improving resource recycling facilities can promote ecological protection.

With regard to planting and crop varieties, compared with vegetables and other herbaceous plants, fruit trees have a better carbon sequestration effect and can enhance biodiversity (Nowak et al., 2013; Johnson and Handel, 2016). Therefore, planting fruit trees can promote ecological protection. Aquatic crops can purify the water environment (Bich et al., 2020), so planting them is positively correlated. However, planting grains is more likely to cause soil hardening and soil fertility loss (Picasso et al., 2011), which has a negative impact on ecological environmental protection. Additionally, the cultivation of flowers requires higher light, humidity, and soil fertility compared to ordinary crops. This leads to increased energy, water, and fertilizer consumption, resulting in excessive resource usage (Falla et al., 2020). Therefore, planting flowers poses a threat to the ecological environment of an edible campus.

In terms of technology application, aquaponics utilizes the nutrient cycle system formed by crops and aquatic animals, which can reduce the input of resources such as water and fertilizer, and minimize waste output (Schröter and Mergenthaler, 2019), thereby alleviating pressure on the ecological environment. Hydroponics, on the other hand, offers clean planting, saves fertilizers, and reduces water consumption (Pomoni et al., 2023). Therefore, it can effectively utilize resources while promoting ecological protection. Because of its high mobility, flexibility, and controllability, container planting can minimize encroachment on green space, save the use of resources like water and fertilizers, thereby protecting the ecological environment. In summary, the use of aquaponics, hydroponics, and container planting can all promote ecological protection.

4.1.5 Economic output benefit and design factors

Regarding spatial carrier, large and concentrated planting spaces can produce high yields at low cost (Roggema, 2021), thus promoting economic output. On the other hand, the construction of pedestrian roads is challenging, and the space area allocated for pedestrian roads is relatively small, which makes it difficult to balance income and expenditure and is not conducive to the economic benefit (Robinson et al., 2017). Therefore, pedestrian roads show a negative correlation.

With respect to space function, more planting functions can result in larger planting area (Zhang et al., 2018), so increasing planting function can promote economic output.

As for planting and crop varieties, compared with vegetables, herbs have higher economic value (Dirks and Orvis, 2005), so planting herbs can increase economic benefits. Additionally, flowers generally command higher prices compared to grains, fruits, and vegetables, so planting flowers can promote economic benefits.

4.2 Design strategies for an edible campus under different benefit orientations

The design of an edible campus is directly related to the realization of its benefits. This section combines the correlation mechanism between design factors and benefits showed in section 4.1, and proposes design strategies under different benefit orientations to guide edible campus design practices.

In order to enhance the educational benefits of an edible campus, planning and site selection should prioritize the use of campus residential areas to build agricultural gardens or farms. Residential areas have a high volume of pedestrian traffic and are highly clustered, which can increase student attention to edible campuses and provide convenience for education promotion. For example, the rooftop garden located in AMN Student Housing greatly promotes communication among students from different ethnic and cultural backgrounds. Secondly, safety facilities should be enhanced with measures such as adding handrails, fences, accessible entrances, wide pathways, ramps, and raised planting containers to encourage educational activities participation by disabled individuals, thereby increasing overall participation rates. Additionally, there should be a focus on increasing the proportion of rooftop gardens, educational functions and reducing recreational facilities, as well as utilizing container gardening. It is important to consider the actual allocation of teaching and research spaces within the school when deciding whether to establish an edible campus in the academy teaching area of different departments.

With a view to promoting the physical and mental health benefits of an edible campus, it is advisable to avoid constructing it in public teaching areas. Instead, it is preferable to integrate it with the central landscape. Additionally, there should be an appropriate increase in the proportion of planting functions, along with improvements in the distribution of educational facilities. Animal and poultry farming can also be considered. However, the proportion of energy production function and aquatic crop cultivation should be reduced. When selecting technologies, it is important to consider scientific experiments to further evaluate the beneficial and healthy techniques.

To promote the social interaction benefits of an edible campus, it is important to consider increasing the proportion of socializing functions. Therefore, public social spaces with adaptability to different locations can be constructed within the edible campus. In larger spaces, these spaces can be located at the center of the edible campus or in areas where paths converge, thereby enhancing social interaction by gathering crowds in a concentrated space. In smaller spaces, public social spaces can be configured by sharing space with planting areas. For example, the public interaction platforms built at the ends of various paths on the H-shaped rooftop farm of National University of Political Science and Law of Thailand have become venues for teacher-student entertainment, gatherings and other activities, effectively increasing communication among them. Furthermore, it is advisable to improve entertainment service facilities, make appropriate use of vertical planting, and reduce the reliance on container planting.

As for the ecological and environmental benefits of an edible campus, it is necessary to prioritize the selection of central landscapes and large-sized spaces in order to establish a complete ecological connection. Secondly, it is important to allocate planting functions appropriately, utilize resource recycling facilities, increase the proportion of fruit trees and aquatic crops, and reduce the cultivation ratio of grain and flowers. Additionally, the application of aquaponics, hydroponics, and container planting techniques can be appropriately increased.

In order to achieve an increase in economic output, it is necessary to integrate the edible campus with central landscapes. This can also be achieved by appropriately increasing the proportion of planting functions, as well as enhancing the cultivation ratio of herbs and flowers. At the same time, it is important to avoid using spaces with high construction costs, such as pedestrian walkways.

5 Limitation and future research

Taking the South Campus of Hebei University of Technology as an example, this paper conducted a comprehensive and in-depth study of key design factors that promote the benefits of an edible campus. However, there are still some limitations in this study. First of all, because the design factors and benefit factors proposed in this paper are derived from literature search and screening, the results are inevitably affected by the research perspective and personal subjective cognition. Secondly, the key design indicators that affect the benefits of edible campuses obtained in this paper are mainly based on a case study. Thus, the methodology highlighted here (designing indicators and benefit indicators identified) needs to be tested across various geographies before concrete and generalizable answers can be found. It is necessary to fully consider the influence of cultural preferences under different environments on the research results and adjust and apply the edible campus design strategy accordingly. However, this study has taken a novel first step in this direction. In addition, future research can also obtain more accurate data by increasing the number of research subjects. For example, conducting a comparative study of edible campuses in different geographical and climatic regions or exploring the differences between old and new universities in developing an edible campus to verify the design factors proposed in this paper.

6 Conclusion

The escalating issues of high food demand, imbalanced diets, food waste, and environmental degradation on Chinese campuses require urgent attention. The economic, social, ecological, and health benefits of an edible campus can effectively address these challenges while enhancing the green environment. Edible campus design plays an important role in promoting these benefits. However, there is a significant lack of research on the relationship between edible campus design and its benefits. This study not only proposes edible campus solutions to how Chinese campuses deal with population growth and food safety issues but also constructs an edible campus design matrix, benefit matrix, and benefit analysis path, which can provide guidance for edible campus practices outside of China. For example, an edible campus can address the food insecurity, and high obesity rates faced by American campuses by intervening in student dietary intake and behavior (Davis et al., 2011; Macchi and Coccia, 2022). Additionally, it can help students establish environmental protection concepts and promote sustainable urban development through environmental education (Jans-Singh et al., 2020; Torrijos et al., 2021).

The main contributions of this paper include: (1) Constructing an edible campus design matrix and benefit matrix, which includes macro-scale site selection and micro-scale spatial organization. The design matrix encompasses 52 design indicators across 7 categories of design elements, namely spatial location, spatial carrier, size, space function, facility configuration, planting and crop varieties, and technology application. (2) Identifying that the main benefits of an edible campus include environmental education, physical and mental health, social interaction, ecological protection, and economic output. (3) Determining the correlation between design indicators and benefit indicators of an edible campus. The findings revealed that the planting function exhibits the highest positive correlation with the five benefits, followed by central landscape and container planting. (4) Proposing benefit-oriented edible landscape design strategies. Based on the correlation analysis, it is recommended that an edible campus prioritize planting functions, integrate with central landscapes, and incorporate container planting. Furthermore, it is crucial to develop detailed spatial designs that cater to different types of benefits. For instance, when considering social interaction benefits, the design should focus on increasing the proportion of entertainment service facilities and emphasizing socializing functions.

This study can create a roadmap for policy makers to test and implement design interventions and regulations that successfully incorporate edible campuses in the planning process. Policy makers can refer to the design matrix and design indicators of this study to establish edible campus design guidelines or best practice cases. This will help guide inexperienced campus gardeners, determine appropriate locations, and develop reasonable design schemes (Katherine, 2015). By doing so, it will effectively harness the positive role of edible campus design and maximize its benefits, while also mitigating implementation obstacles. As edible campuses continue to evolve, policy makers should also incorporate them into laws, regulations, or local planning to ensure the legitimacy of edible campuses and improve the utilization efficiency of their resources. For instance, research conducted by Turner et al. (2017) confirmed that edible campuses supported by state laws achieve better nutritional and health benefits compared to edible campuses without legal support.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by School of Architecture & Art Design, Hebei University of Technology. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

XD: Conceptualization, Formal analysis, Methodology, Writing – original draft. SZ: Formal analysis, Writing – review & editing. XY: Resources. YX: Supervision. ZZ: Investigation, Software, Writing – original draft.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work was funded by the Hebei Provincial Natural Science Foundation project (grant no. E2021202079), Collaborative Research Project of the "Chunhui Program" of the Ministry of Education (grant no. HZKY20220262), Science and Technology Project of Hebei Education Department (grant no. SQ2022074).

Acknowledgments

We specially thank Zhongwang Zhang, Xiaoyu Zhang, and Weike Li for supporting data collection.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1267894/full#supplementary-material

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