The Unsold Food Pathway: Cold Storage Facilities and Dietary Diversity among Migrant Food Vendors in Nanjing, China

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Abstract

Previous studies have largely overlooked the potential impact of cold storage facilities on household dietary diversity. To address this gap, this study draws on survey data collected from migrant food vendors in wet markets in Nanjing City, China. It proposes two pathways linking cold storage sufficiency to vendors' household dietary diversity and tests these mechanisms using path analysis based on Generalised Structural Equation Modelling (GSEM). The results show that greater sufficiency of cold storage facilities led to higher dietary diversity in migrant food vendors' households, primarily by reducing the consumption of unsold food. In contrast, no significant effect is found along the pathway linking storage facilities to business hours, time allocated to food-related activities, and dietary diversity. By uncovering the "unsold food" pathway, the study contributes to urban food security and food environment research by demonstrating that food system actors may experience limited dietary diversity despite operating in food-rich environments. The paper calls for policy measures, such as subsidised cold-storage equipment and improved electricity use, to reduce food spoilage, improve dietary diversity among vendors, and help address hidden hunger in urban settings.

Keywords

market facilities, cold storage, wet market vendors, dietary diversity, internal migrants, China

Suggested Citation

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Cover Image

Meat and poultry section with refrigerated display cases at a wet market in Nanjing. Photo credit: Taiyang Zhong

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Introduction

Existing studies on food vendors' working conditions highlight exposure to multiple poor working conditions, particularly infrastructure deficiencies such as insufficient access to potable water, electricity and sanitation (Nkosi & Tabit, 2021). It is common for small food vendors such as street vendors and those operating in informal or traditional markets to have inadequate equipment or limited access to infrastructure and facilities (Cahya, Subroto & Sakti, 2025; Farahat, El-Shafie, & Waly, 2015; Kushitor et al., 2022). Inadequate equipment and facilities usually increase the food's exposure to contamination and spoilage (Monney, Agyei, & Owusu, 2013; Wallace et al., 2022), thereby increasing the risk of food safety issues for consumers (Moges, Rodland, & Argaw, 2024). For vendors operating in open-air or wet markets, inadequate infrastructure is a frequent problem, such as the absence of proper cold storage and sanitation facilities (Wallace et al., 2022). These challenges have been a major cause of food loss in retail (Realpe, Scalco, & Brancoli, 2024).

Although the impacts of inadequate access to retailing facilities (e.g., cold storage facilities, food service infrastructure and equipment) on food safety (Nkosi & Tabit, 2021), food waste or loss (Peira et al., 2018; Yan, Song, & Lee, 2021) and operating costs or returns (Andukuri, Mahendran, & Choyal, 2025) are well documented, far fewer studies have investigated how such inadequacies affect vendors themselves. Existing evidence has primarily focused on occupational health. For example, one study highlights how undesirable working environments increase vendors' exposure to air pollutants. A cross-sectional pilot study in South Africa revealed that poor working conditions were a risk factor for respiratory symptoms among food vendors, especially those selling cooked foods (Sepadi & Nkosi, 2022).

Even fewer studies have explored the implications of inadequate infrastructure and equipment for vendors' food security. This gap may reflect an implicit assumption that by virtue of their occupation, food vendors are unlikely or at least less likely to experience food insecurity. However, food security is a multidimensional concept that encompasses not only food availability and access but also utilization, including dietary diversity, which is closely linked to nutrition and health outcomes. Emerging research challenges this assumption, showing that food vendors and other food system workers can experience varying degrees of food insecurity and compromised dietary quality, particularly in contexts of informal employment and income instability (Crush & Frayne, 2011; Khan, 2024; Zhong et al., 2026). Against this backdrop, this study examines the linkages between access to facilities, particularly cold storage, and food vendors' household dietary diversity. By focusing on dietary diversity as a key dimension of food security, it contributes to a more nuanced understanding of how infrastructural constraints shape not only market outcomes but also vendors' well-being.

The paper is structured as follows. The next section reviews the literature on the food security of food vendors and the effects of storage facilities in food markets. Building on this, the paper next develops the theoretical framework, linking food facilities to household dietary diversity. After that, the data, methodology, and variables used in the analysis are described. The subsequent two sections present the empirical results, followed by a discussion of these findings in relation to existing literature and their implications for urban food security and food environments. The paper concludes with some policy implications.

Food Vendors' Food Security and Impacts of Storage Facilities in Food Markets

A growing body of literature investigates the role of food vendors in contributing to urban food security (Adeosun, Greene, & Oosterveer, 2022; Hannah et al., 2022; Ibrahim, Robert, & James, 2024). However, less attention has been paid to the vendors' own food security. Emerging evidence from the MiFOOD Network points to the vulnerability of informal food vendors, particularly during the COVID-19 pandemic, though it primarily focuses on their income instability and food access rather than their own dietary outcomes. For example, studies in Jamaica, Namibia, and Kenya document how COVID-19 disruptions and broader livelihood precarity affect the earnings and food access of informal food vendors (Dietrich Jones, Johnson, & Reid, 2026; Nickanor et al., 2026; Odhiambo et al., 2025; Owuor et al., 2025). Lockdowns in Nigeria during the COVID-19 pandemic also reduced incomes and thus constrained food access among street food vendors (Majing & Regina, 2021). Recent MiFOOD research on other food system actors, such as delivery riders, further confirms limited dietary diversity among food workers (Zhong et al., 2026).

Existing studies have also examined multiple factors influencing the food security of food vendors and their households, with a strong emphasis on income-related determinants. Evidence from Gaborone, Botswana, shows that income generated from food vending plays an important role in improving the diets of street food vendors' households (Kasimba et al., 2022). Gender differences shape how such income translates into household food security outcomes, as male and female vendors tend to allocate income differently (Levin et al., 1999). As income plays a primary role in determining household food security, any factor affecting vendors' earnings will impact the food security of vendors and their households. For instance, climate-related challenges have increased business vulnerability among women market vendors in Vanuatu, further reducing their households' food security, especially where food vending income is a main source of livelihoods (Kilroy et al., 2026).

Beyond income-related factors, infrastructure conditions within marketplaces may also play a critical role in shaping vendors' food security. In particular, inadequate food storage facilities make it harder for vendors to prevent spoilage, which in turn influences their vending practices and handling of unsold or surplus food. Food vendors in traditional markets, such as wet markets, frequently struggle to manage perishable goods due to poor infrastructure and

insufficient storage facilities (Kushitor et al., 2022; Wawire et al., 2025). Evidence from Tanzania suggests that consuming unsold food is a common strategy among young women food vendors to reduce food expenditures (Mhando & Mramba, 2021). While using freezers can help delay deterioration in quality and taste, many vendors lack access to such facilities. Instead, they rely on alternative strategies to slow spoilage, such as shielding foods or storing them in relatively cool places (Adeosun, Greene, & Oosterveer, 2022). In China, wet market vendors commonly spray water on leafy vegetables to maintain their fresh appearance in the absence of open-air cooling systems (Zhong, Crang & Zeng, 2020). In addition, studies have shown that inadequate storage facilities can contribute to vendors' income losses and improvements to the infrastructure of traditional markets can increase vendors' income (Kushitor et al., 2022; Saputra & Sembiring, 2025).

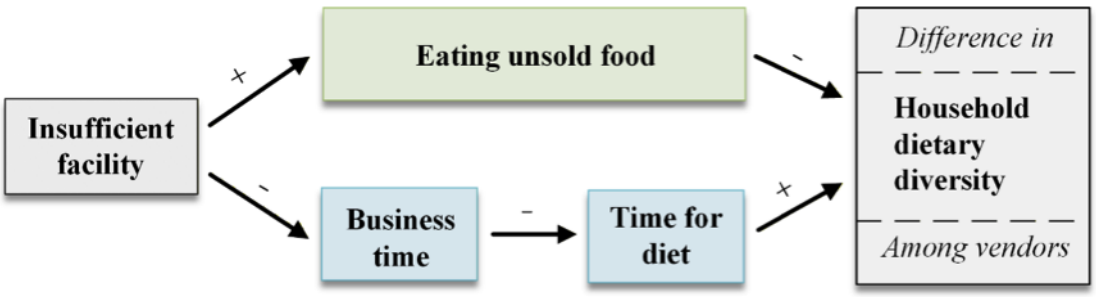
Despite the increase in studies on food vendors' roles in urban food security and the factors shaping their livelihoods and food security, important gaps remain. Existing studies focus predominantly on street or mobile vendors, with little attention to vendors operating in fixed market settings. Moreover, they largely emphasize income-related determinants and dynamics while overlooking other important factors, such as marketplace infrastructure, including food storage facilities. Little attention has been paid to how storage constraints shape vendors' personal and household food consumption practices, especially in the handling and consumption of unsold food. The implications of these limitations for vendors' household dietary diversity remain unexplored. To address these gaps, this study proposes and empirically tests potential pathways linking food storage constraints to household dietary diversity, using survey data on migrant food vendors' business operations and household food consumption.

Theoretical Framework Linking Food Facility and Dietary Diversity

There are two potential pathways through which insufficient retail food facilities impact food vendors' household dietary diversity. The first is "food facility→ unsold food → dietary diversity", which we referred to as "unsold food path" (Figure 1). Products sold in wet markets can be broadly categorized into perishable foods, such as vegetables and meat, and less perishable or stable foods, such as cereals and nuts (Bourne, 2014). Perishable foods are more susceptible to loss than less perishable foods. Among perishable foods, meat is generally more perishable than vegetables and fruits (Bourne, 2014), suggesting that meat vendors are more likely to incur higher losses than vendors of vegetables and fruits. However, two factors suggest that vegetable vendors may face higher losses than meat vendors in China. First, most meat vendors in Chinese food markets have access to refrigeration to store unsold meat, whereas vegetable vendors typically lack cold storage and display their produce at room temperature in their stalls. As a result, unrefrigerated vegetables may deteriorate faster than meat stored in refrigerators. Second, Chinese consumers have a strong preference for food freshness and frequently buy fresh produce to ensure it (Zhong, Crang & Zeng, 2020). Vegetables that have been displayed at room temperature for a long time usually look less fresh and are therefore difficult to sell the next day. To reduce income loss from unsold food, vegetable vendors and their household members consume the unsold food, thereby reducing their need to purchase a wide variety of foods and, in turn, potentially reducing their household dietary diversity. Conversely, meat vendors are more able to preserve unsold products and sell them on subsequent days, making them less likely to experience adverse effects on their household dietary diversity.

Another pathway is "food facility→ business time → feeding affair time → dietary diversity", which is what we referred to as "feeding time path" (Figure 1). Some empirical studies have indicated that time scarcity can reduce diet quality (Venn & Strazdins, 2017). In particular, time scarcity increases the possibility of eating out (Venn & Strazdins, 2017). An increase in time spent on food activities away from home has been associated with lower diet quality, including decreased consumption of nutritious foods such as vegetables and fruits (Carpio et al., 2020). Access to retail food facilities may influence vendors' working hours and, consequently, affect the time available to them for food-related activities, especially purchasing and preparing meals. Vendors lacking facilities that ensure food freshness for extended periods, such as refrigerators or refrigerated display cases, may operate for shorter hours due to faster spoilage, whereas those who can store their selling foods in refrigerators can extend their business hours. Longer working hours may reduce the time available for home food preparation and consumption, further decreasing dietary diversity. Conversely, insufficient facilities may shorten business hours and thus increase the time spent on feeding affairs, which further increases dietary diversity.

Figure 1: Pathways of Facility Insufficiency Affecting Vendors' Household Dietary Diversity



Methodology and Data Sources

The previous section of this paper outlines potential pathways linking food storage facilities to vendors' household dietary diversity. However, these relationships remain theoretically inferred and may vary across contexts. Empirical evidence is thus needed to disentangle the various factors influencing vendors' household dietary diversity and to test the mechanisms underlying these influences. Survey data at the household level, capturing both business practices and food consumption patterns, provide a suitable basis for testing these mechanisms and identifying the dominant pathways in practice. This section will discuss the survey conducted in Nanjing, the variables, and the regression analysis method used.

Food Vendor Survey

Nanjing city was selected as the case study to conduct a survey of vendors in wet markets. Nanjing is located in eastern China, about 300 kilometres from Shanghai, or about 1 hour by high-speed train. Public food markets, usually called "wet markets" in English-speaking countries, are the most important food sources for the urban population in contemporary China (Zhong et al., 2023). As the Chinese central government has mandated the establishment of public food markets near residential neighbourhoods, more than 400 wet markets were distributed across Nanjing in 2019, largely located near residential areas (Zhong et al., 2023). A 2015 study found that more than 90% of Nanjing households purchased fresh food from wet markets, and about 75% of households visited wet markets at least five days a week (Si & Zhong, 2018). Despite the rapid growth of commercial food retailing and e-commerce in recent years in China (Dai, Stephens, & Si, 2024; Liang, Zhong, & Crush, 2022), our household-level food security survey conducted in 2022 and 2023 indicated that wet markets remained central to food access, with roughly 60% of households visiting them at least five days a week and more than 97% visiting at least once a week. Our 2017 survey showed that on average, there were 40 food stalls or stores within a wet market in Nanjing (Si & Zhong, 2019). Around 65% of vendors in wet markets in Nanjing were migrants from rural areas or other urban areas in China (Zhong, Si, & Yuan, 2025). Based on this understanding of the significant presence of migrants among food vendors, this study focused on migrant food vendors in Nanjing. We conducted a questionnaire-based survey about their food business and household food security status from September to October 2024.

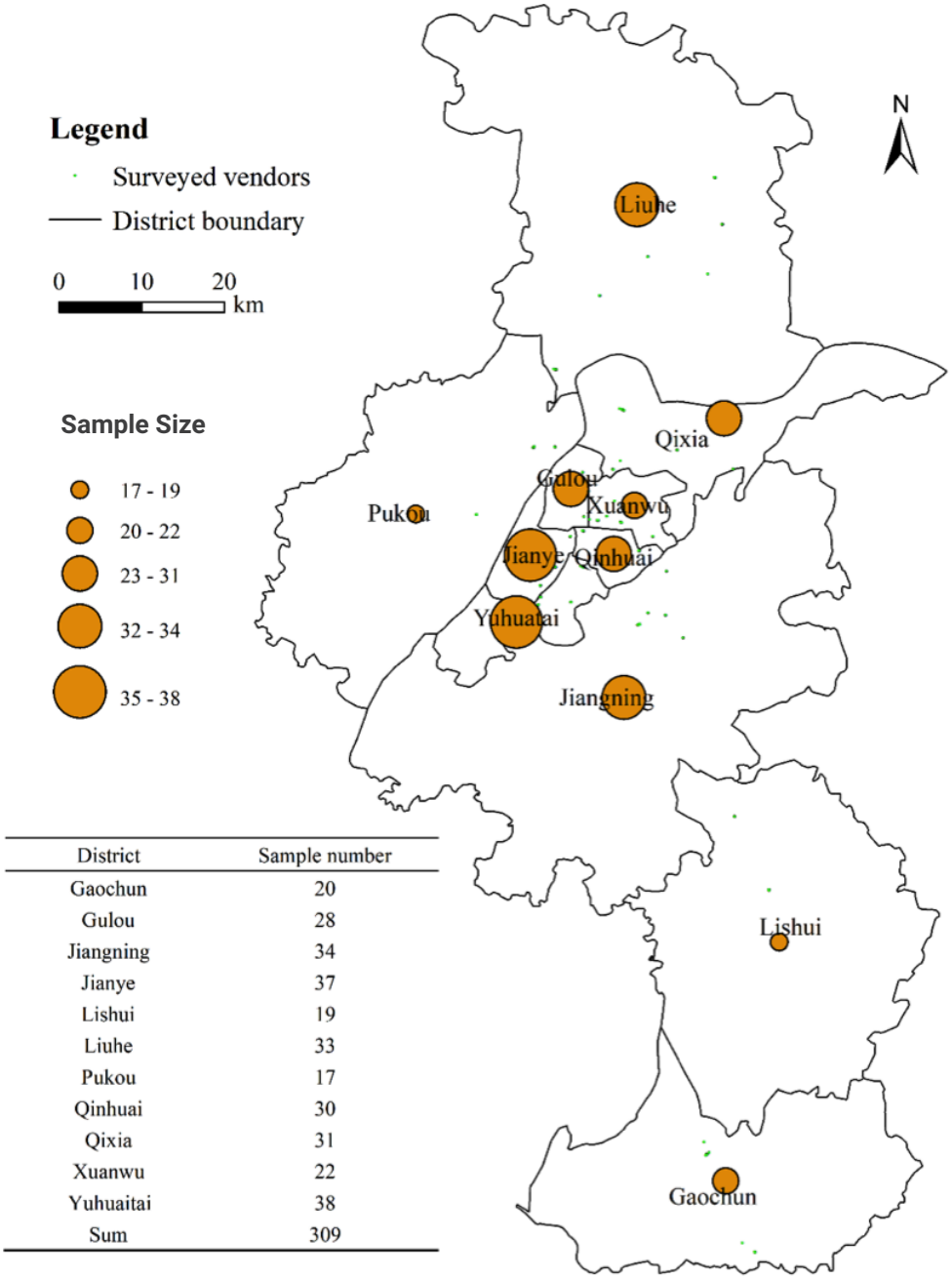
Food vendors surveyed in this study were selected using a three-step sampling method. First, information on wet markets, such as their names and locations, was updated using the 2017 list of wet markets, which was compiled when a survey of wet market vendors was conducted in Nanjing (Si & Zhong, 2019). The updated list combined official records from the Nanjing Municipal Government with additional markets identified via the Baidu Map Application Programming Interface , which provided supplementary location information for markets not included in the official list. Second, wet markets were sampled by considering both those surveyed in 2017 and changes in the market landscape between 2017 and 2024. Third, migrant vendors were purposively selected for the survey, while non-migrant vendors were excluded. In total, the study obtained a sample of 312 migrant food vendors from 43 wet markets.

The survey included four sets of questions about vendors' or their household's diet. The first set concerns household dietary diversity. This study uses the Household Dietary Diversity Score (HDDS) to measure household diet quality. The HDDS comprises 12 food groups, including (a) four animal-source food groups such as meat, poultry, offal, eggs, fish and seafood, (b) five plant-based food groups such as cereals, root and tubers, vegetables and fruit, and pulses/legumes/nuts, and (c) other food groups including oil/fats, sugar/honey and miscellaneous (Swindale & Bilinsky, 2006). The HDDS, ranging from 0 to 12, is computed for each household as the number of food groups consumed the day before the survey (Swindale & Bilinsky, 2006). The second set of nine questions in the survey measures the Household Food Insecurity Access Scale (HFIAS). Every HFIAS question has four response options for frequency of occurrence, including "Never/no=0", "Rarely=1", "Sometimes=2", and "Often=3". The HFIAS is calculated as the sum of responses across all nine questions, yielding a total score ranging from 0 to 27 (Coates, Swindale, & Bilinsky, 2007). The third set is about migrant vendors' breakfast practices, which includes four questions: means of having breakfast, timing, frequency of skipping breakfast and reasons for skipping. The fourth set is about their lunch and includes four questions on the means, timing, frequency, and reasons for lunch consumption. While the HFIAS and HDDS assess household-level food security and dietary diversity, the third and fourth sets of questions capture individual breakfast and lunch patterns.

Dependent Variable

HDDS (the variable *hdds*) is used as the dependent variable in this study. On average, vendor households exhibit higher food insecurity than city-wide households, as reflected by a mean HFIAS of 1.19 compared to 0.60. Considering that the HFIAS ranges from 0 to 27, the difference of 0.59 is relatively small. The nine questions of HFIAS can be grouped into three domains: food anxiety (Q1), food quality (Q2-Q4), and food quantity (Q5-Q9). Table 1 indicates that food quality was the main domain resulting in the difference in HFIAS between food vendors' households and city-wide households. Moreover, the mean HDDS of vendor households is 4.79 compared to 7.39 for city-wide households, resulting in a difference of 2.60. Considering that HDDS ranges from 0 to 12, the difference of 2.60 is much more significant compared to the difference observed in HFIAS (0.59). This indicates a more pronounced disparity in dietary diversity. Therefore, this study investigates variations in HDDS across vendors selling different types of food, with particular attention to why households of vegetable vendors had lower HDDS than those of vendors selling animal food, grain, and oils.

Figure 2: Distribution of Surveyed Migrant Food Vendors within Wet Markets



District	Sample number
Gaochun	20
Gulou	28
Jiangning	34
Jianye	37
Lishui	19
Liuhe	33
Pukou	17
Qinhuai	30
Qixia	31
Xuanwu	22
Yuhuaitai	38
Sum	309

Table 1: Percentage of Response to Occurrence Frequency for HFIAS Questions

Question	City-wide household				Vendor			
	0	1	2	3	0	1	2	3
Q1	91.4	6.9	1.2	0.5	91.0	6.4	2.3	0.3
Q2	90.9	7.2	1.5	0.4	81.4	12.2	6.1	0.3
Q3	88.8	8.4	2.1	0.8	82.1	13.1	3.5	1.3
Q4	94.1	4.6	1.0	0.3	89.1	7.1	3.8	0.0
Q5	95.5	3.1	1.1	0.2	93.9	3.5	1.9	0.6
Q6	97.6	1.7	0.4	0.2	94.2	2.9	2.6	0.3
Q7	97.8	1.6	0.5	0.1	93.6	3.5	2.2	0.6
Q8	98.5	1.1	0.3	0.1	94.9	3.2	1.9	0.0
Q9	98.5	1.1	0.3	0.1	94.6	3.8	1.3	0.3

Source: Calculated from survey data collected in 2024 and 2022/2023

Facility Sufficiency and Explanatory Variable

The survey questionnaire included a query about food storage facilities: "What kind of food storage do you currently have available at this shop?" There were six options for this question, including cold room, open-front refrigerated display cabinet/case (open cooler), refrigerator, cooler box, locked box, and others. The variable *ycooling* was created to reflect the adequacy of migrant vendors' food cooling facilities, with a value of 1 if the response included any of the three options: cold room, open-front refrigerated display cabinet/case (open cooler) or refrigerator; otherwise, "0" if none of the three options were selected.

Other Variables

Unsold food is a common reality for food vendors, yet little attention has been paid to how they manage it (Peira et al., 2018). A study of Italian outdoor markets shows that farmers and peddlers adopt different practices for handling unsold food, including donation, discount sales, reuse in organic forms such as composting, and consumption by the vendor's own household (Peira et al., 2018). Consumption by vendors' own households is common among food operators in Italian outdoor markets, accounting for nearly 60% of these operators, including farmers, peddlers, and hybrid operators (Peira et al., 2018). Our fieldwork in wet markets in Nanjing indicates that food vendors also commonly eat their unsold food. The variable *yunsold* indicates whether vendors' households eat unsold food. One question asked how vendors had disposed of spoiled or non-fresh food in the past year, with one option being "consumed by my family or given to relatives". The binary variable *yunsold* was given a value of 1 if the vendor selected this option, 0 otherwise. As analyzed in the previous section, vendors eating unsold non-fresh food could decrease their household dietary diversity. Accordingly, variable *yunsold* is expected to have a negative coefficient when *hdds* is treated as the dependent variable.

As noted in a previous section, time spent on food-related activities is another potential factor influencing household dietary diversity. Because our survey did not collect information on vendors and their household members' time allocation to feeding-related activities but collected information on the food vendors' own situation regarding breakfast and lunch practices, this study uses meal skipping as a proxy for reduced time devoted to food-related activities, represented by the variable *yskip*. The variable *yskip* was assigned a value of 1 if the vendor skipped breakfast or lunch, and 0 otherwise. If a vendor skips breakfast or lunch, their household is more likely to allocate less time to food-related activities than households that do not skip meals. Time scarcity could increase the risk of skipping meals (Jabs & Devine, 2006), which is usually associated with poor dietary quality, such as reduced dietary diversity or less healthy food intake (Azadbakht et al., 2013). Therefore, the variable yskip is expected to have a negative coeffi cient when the equation uses *hdds* as the dependent variable and *yskip* as the independent variable.

Household size is another commonly reported factor influencing household dietary diversity. Some studies have shown a positive association between household size and household or individual dietary diversity (Sibhatu, Krishna, & Qaim, 2015; Vijay & Kumar Patel, 2021). This study used the variable *hhsize* to represent household size and its coefficient was expected to be positive when the equation uses *hdds* as the dependent variable.

The food environment, which often refers to diversity, density and proximity of food outlets within a geographical area, plays an important role in determining dietary choice (Bernsdorf et al., 2024) and therefore impacts dietary diversity (Liu et al., 2022). Therefore, the variable *nsource* was generated based on the question of "How did your household obtain food in the past six months?" The value of the variable *nsource* was the number of options the vendor selected. Higher exposure to diverse food outlets is associated with higher dietary diversity (An, He, & Shen, 2019). The coefficient of the variable *nsource* is expected to be positive when *hdds* is treated as the dependent variable.

Business hours are another important factor influencing food vendors' dietary diversity, as longer working hours could increase the likelihood of meal skipping. Meal skipping commonly reflects differences in the time allocated to food-related activities, such as grocery shopping and meal preparation, which could further affect dietary diversity. Hence, the variable *dailyhour* was used to refer to the number of daily business hours, which is assumed to have a positive coefficient in the equation where *yskip* is treated as the dependent variable. In addition, there could be significant differences in business hours among vendors selling different kinds of food. Therefore, vendors were categorized into animal food (meat), fruit, vegetables, grains or cooking oil vendors. Three dummy variables were created to indicate whether the vendor sells animal food, fruit, and vegetables: *yanimal*, *yfruit*, and *yvegetable*, respectively. Table 2 presents the descriptive statistics and definitions of variables.

Regression Analysis Model

Based on the theoretical analysis presented in a previous section, the study examines the following potential paths between variables as mentioned above when food cooling facility sufficiency was considered (Figure 3).

- The path of "*ycooling* → *yunsold* → *hdds*", which refers to the path of "insufficient facility → increasing possibility of eating unsold food → decreasing household dietary diversity" or "sufficient facility → decreasing possibility of eating unsold food → increasing household dietary diversity".

- The path of "*ycooling* → *dailyhour* → *yskip* → *hdds*", which refers to the path of "insufficient facility → decreasing business time → decreasing hazard of skipping meals → increasing household dietary diversity" or "sufficient facility → increasing business time → increasing hazard of skipping meals → decreasing household dietary diversity".

Table 2: Descriptive Statistics and Definitions of Study Variables						
Variable	**Definition, type and range**	**N**	**Min**	**Max**	**Mean**	**Std. dev.**
Hdds	Household dietary diversity, count, 0-12	310	1	12	4.79	2.11
ycooling	Cooling facility sufficiency, whether having a food cooling facility, binary, 1 for yes and 0 for otherwise	312	0	1	0.49	0.50
yunsold	Whether vendor households eat unsold food, binary, 1 for yes and 0 for otherwise	312	0	1	0.96	0.20
Yskip	Whether the vendor skip breakfast or lunch, binary, 1 for yes and 0 for otherwise	306	0	1	0.46	0.50
Hhsize	Household size, continuous	308	1	8	3.24	1.41
nsource	The number of vendor households' food sources, continuous, 0-26	312	0	11	1.97	1.25
dailyhour	Business time, referring to vendor's daily work hours, continuous, 0-24	303	4.0	17.0	11.86	2.58
Yanimal	Whether the vendor sells meat, fish and other animal foods, binary, 1 for yes and 0 for otherwise	312	0	1	0.50	0.50
Yfruit	Whether the vendor sells fruit, binary, 1 for yes and 0 for otherwise	312	0	1	0.08	0.28
yvegeta-ble	Whether the vendor sells vegetables, binary, 1 for yes and 0 for otherwise	312	0	1	0.36	0.48

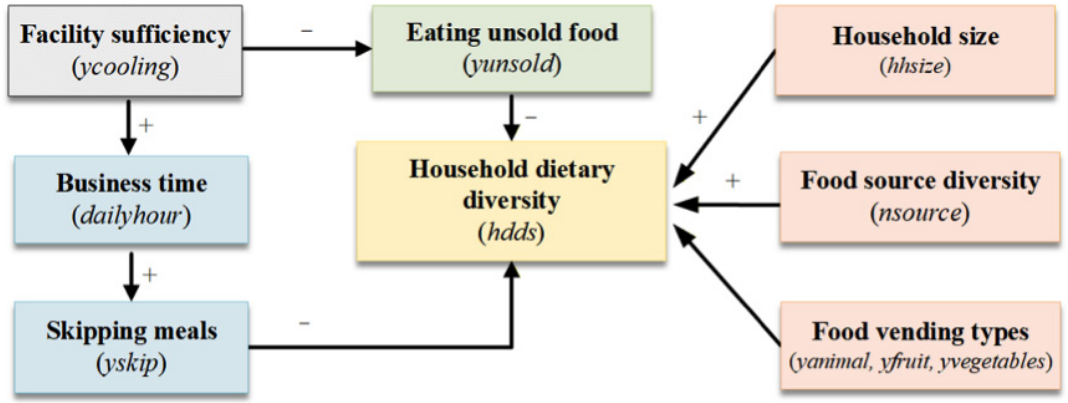
- The direct impact of the variable *hhsize* on *hdds* and from the variable nsource on *hdds*.

Because the variable *ycooling* represents the sufficiency of food cooling or refrigeration facilities, vendors with such facilities (the value of *ycooling* is 1) may be less likely to eat unsold food. Therefore, the variable *ycooling* is assumed to have a negative coefficient in the equation where *yunsold* was used as the mediator or dependent variable.

A lack of refrigeration facilities could shorten vendors' daily business hours, so those with food cooling facilities (i.e., *ycooling* = 1) would have longer business hours than those without such facilities (i.e., *ycooling* = 0). Accordingly, the variable ycooling is assumed to have a positive coefficient in the equation where dailyhour is specified as a mediator or a dependent variable. Besides, the three variables representing the types of food sold by vendors (i.e., yanimal, yfruit, and yvegetable) are considered potential factors influencing migrant food vendors' daily business hours. Compared with vendors selling grain and cooking oil, those selling animal food, fruits and vegetables are expected to have longer business hours. The coefficients of *yanimal*, *yfruit* and *yvegetable* are thus assumed to be positive in the equation where *dailyhour* is used as a mediator or a dependent variable.

Path analysis based on GSEM (Generalized Structural Equation Modeling) is used to examine the two potential paths identified earlier. HDDS is commonly treated as a count variable, although a few studies have treated it as a continuous variable (Kundu et al., 2020). This study treated HDDS both as a count and a continuous variable in the analysis. The "*nlcom*" command in STATA is used to test the presence of indirect effects of food facility insufficiency or sufficiency on migrant food vendors' household dietary diversity, and to calculate the coefficients of corresponding indirect effects.

Figure 3: Potential Pathways from Facility Sufficiency to Household Dietary Diversity



Results

Migrant Vendor Household Food Security and Dietary Diversity

Table 3 shows a slight difference in frequency distribution of HFIAS between migrant vendor households and citywide households. The share of households with an HFIAS score of 0 was 75.2% among migrant vendors, compared to 79.9% citywide. Based on the response to the nine HFIAS questions, households can be categorized into four groups, including food secure, mildly insecure, moderately insecure, and severely insecure. Among city-wide households, 82.7% are food secure, 9.5% mildly insecure, 4.9% moderately insecure, and 3.0% severely insecure. In comparison, migrant vendor households show a lower level of food security, with 76.6% food secure, 13.8% mildly insecure, 2.2% moderately insecure, and 7.4% severely insecure.

The nine questions of HFIAS capture three domains of food insecurity: food anxiety (Q1), food quality (Q2-Q4) and food quantity (Q5-Q9) (Coates et al., 2007). Among migrant vendor households, 91.0% reported no experience of food anxiety, and 92.0% reported no issues related to food quantity (i.e., a value of zero indicating 'never'). In contrast, only 77.2% reported no problems with food quality, suggesting that nearly one-quarter of migrant vendor households experience some degree of constraint in food quality. These figures indicate that the major problem affecting the food security of migrant vendor households is food quality.

Table 4 shows a significant difference in the frequency distribution of HDDS between migrant food vendor households and citywide households. Approximately 87.8% of citywide households had an HDDS of at least 5, compared with only 47.1% of migrant vendor households, roughly half the proportion. Similarly, 48.4% of citywide households had an HDDS of at least 8, whereas only 12.3% of migrant vendor households reached this level. These disparities are also reflected in the mean HDDS, which is 7.39 for citywide households and 4.79 for migrant vendor households, indicating a substantial gap in dietary diversity.

Model Estimation Results

As mentioned above, HDDS can be treated as either a count or a continuous variable; therefore, two sets of models were estimated. One set presents estimation results treating HDDS as a count outcome (Models P1 and P2), while the other presents results treating HDDS as a continuous variable (Models O1 and O2). Finally, four models were estimated with the GSEM approach. Table 5 presents the estimation results of these four models. Models P1 and O1 do not include the variables *yanimal*, *yfruit* and *yvegetable*,

Table 3: The Percentage and Cumulative Percentage of Vendor and City-Wide HFIAS

HFIAS	Percentage		Cumulative percentage	
	vendor	city-wide	vendor	city-wide
0	75.2	79.9	75.2	79.9
1	7.1	8.0	82.3	87.9
2	6.4	4.9	88.8	92.8
3	1.6	1.8	90.4	94.6
4	1.6	1.9	92.0	96.4
5	0.6	0.9	92.6	97.3
6	1.0	0.9	93.6	98.2
7	1.3	0.2	94.9	98.5
8	1.0	0.5	95.8	99.0
9	0.3	0.5	96.1	99.5
10	0.6	0.2	96.8	99.7
11	0.6	0.0	97.4	99.7
13	0.3	0.0	97.8	99.7
14	0.3	0.1	98.1	99.7
16	0.0	0.1	98.1	99.8
17	0.3	0.1	98.4	99.8
18	0.3	0.0	98.7	99.8
19	0.6	0.0	99.4	99.8
20	0.3	0.1	99.7	99.9
21	0.0	0.1	99.7	99.9
22	0.3	0.0	100.0	99.9
27	0.0	0.1	100.0	100.0

Source: Calculated from surveys conducted in 2024 and 2022/2023

whereas models P2 and O2 include these variables. The estimation results show that all coefficients are statistically significant except the variable *yvegetable*.

Both the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were used to compare model performance. Table 5 also presents the AIC and BIC values for all estimated models. The results show that models treating HDDS as a count variable have relatively smaller AIC and BIC values, indicating a better fit than models treating HDDS as a continuous variable. Model P1 has a lower BIC but a higher AIC than model P2. When non-linear models with small samples are considered, BIC is generally considered a better criterion for model selection (Vrieze, 2012). Therefore, model P1 is preferred over model P2, and the following discussion is based on the estimation results of model P1.

Table 4: Percentage and Cumulative Percentage of Vendor and City-Wide HDDS

HDDS	Percentage		Cumulative percentage	
	vendor	city-wide	vendor	city-wide
12	0.3	5.3	0.3	5.3
11	1.0	5.8	1.3	11.1
10	2.3	10.1	3.6	21.2
9	3.2	12.8	6.8	34.0
8	5.5	14.4	12.3	48.4
7	7.1	14.4	19.4	62.8
6	10.0	13.7	29.4	76.5
5	17.7	11.3	47.1	87.8
4	22.6	6.9	69.7	94.6
3	20.7	3.1	90.3	97.8
2	8.4	1.4	98.7	99.2
1	1.3	0.8	100.0	100.0

Source: Calculated from surveys conducted in 2024 and 2022/2023

Table 5: Estimation Results of GSEM and OLS

Variable	Coefficients			
HDDS	P1	P2	O1	O2
Hhsize	0.0284	0.0284	0.1463*	0.1463*
nsource	0.0733***	0.0733***	0.4067***	0.4067***
Yskip	-0.0965*	-0.0965*	-0.4621**	-0.4621**
yunsold	-0.1305**	-0.1305**	-0.6483**	-0.6483**
_cons	1.4083***	1.4083***	3.9276***	3.9276***
Yskip				
dailyhour	0.1478***	0.1478***	0.1478***	0.1478***
_cons	-1.9143***	-1.9143***	-1.9143***	-1.9143***
dailyhour				
ycooling	0.6823**	0.7058**	0.6823**	0.7058**
yanimal		0.9228**		0.9228**
yfruit		1.8692***		1.8692***
yvegetable		0.6212		0.6212
_cons	11.5230***	10.6737***	11.5230***	10.6737***
yunsold				
ycooling	-0.7919***	-0.7919***	-0.7919***	-0.7919***
_cons	-0.7122***	-0.7122***	-0.7122***	-0.7122***
N	312	312	312	312
ll(model)	-1713.7740	-1707.5820	-1724.1520	-1717.9600
AIC	3451.5480	3445.1640	3474.3040	3467.9210
BIC	3496.4640	3501.3090	3522.9630	3527.8090

*Note: ***, ** and * represent significance at the level of 1%, 5% and 10%, respectively*

Discussion

Access to Facilities, Unsold Food and Household Dietary Diversity

Overall, less than half (49.4%) of migrant vendors in wet markets had access to cold storage facilities. However, there was a notable difference in access across vendor types and the food products they sold. Animal-product (meat) vendors have the highest access rate (61.5%), whereas vegetable vendors have the lowest (30.1%). The corresponding figures are 51.7% for grain and cooking oil vendors and 42.3% for fruit vendors. Due to a lack of food cooling facilities, a much higher percentage of vegetable vendor households consumed unsold food than the other three types of vendors. Table 6 shows that 55.8% of vegetable vendor households report eating their unsold foods, followed by fruit vendors at 50.5%. In comparison, 32.7% of vendor households selling animal products/meat and 24.1% of vendor households selling grain or cooking oil report eating unsold foods. The difference between animal-food vendors (the lowest) and vegetable vendors (the highest) is approximately 31%.

When the share of vendors with cooling facilities is compared with the share of households that consume unsold food, a clear inverse relationship emerges. Lower access to cooling storage facilities is associated with a higher likelihood of consuming unsold food. In other words, better access to cooling facilities reduces the probability of consuming unsold food. This relationship is confirmed by the regression results. In Model P1, where the variable *yunsold* is a mediator, the coefficient of the variable *ycooling* is -0.7919 and is statistically significant at the 1% level. This indicates that vendors with cooling facilities (*ycooling*=1) have 54.7017% (100*[$e^{-0.7919}$-1]) lower odds of consuming unsold food ($e^{-0.7919}$=0.4530), holding other variables constant.

Consumption of unsold food is associated with lower household dietary diversity. Households that consume unsold food have a mean HDDS of 4.38, compared to 4.93 among those that do not. This difference is marginally significant based on an analysis of variance (ANOVA) test (N = 310, F = 5.55, p = 0.06). The regression results further support this association. In Model P1, the coefficient of *yunsold* is −0.1305 and statistically significant at the 5% level, indicating that households consuming unsold food (*yunsold*=1) have 12.2% lower expected dietary diversity ($e^{-0.1305}$ = 0.8777), holding other variables constant.

The command of "*nlcom*" in STATA was used to test indirect effects and calculate their coefficients for the path of "*ycooling⟶ yunsold⟶ hdds*". Based on the estimation results of Model P1 in Table 5, the test indicates a statistically significant indirect effect along the pathway "*ycooling⟶ yunsold ⟶hdds*" (p=0.092), with an estimated coefficient of 0.1033. The positive coefficient of the indirect effect indicated that being equipped with cooling storage facilities increased migrant vendor households' dietary diversity. Conversely, a lack of such facilities decreased their dietary diversity.

As cold storage helps prolong shelf life and reduce nutrient loss in fresh produce (Hoffmann et al., 2025), improving vendors' storage facilities could have a double effect on ensuring food security. In addition to the positive effect on food vendors' own household dietary diversity, improvements in food storage facilities can also help reduce hidden hunger caused by micronutrient loss due to a lack of cold storage. Moreover, improvements in food storage could help reduce food loss in food supply chains and thus contribute to boosting food security at the regional or national level (Friedman-Heiman & Miller, 2024; Li et al., 2025). Considering that more than half of migrant food vendors in wet markets are already equipped with cold storage facilities, it is reasonable for the government to support the wider adoption of such facilities. Although vendors in wet markets benefit from discounted electricity prices (Zhong et al., 2019), the fieldwork for this study finds that some vendors equipped with refrigerators only use them intermittently, by switching off the power after cooling and storing unsold food, to reduce electricity costs. This suggests that financial constraints remain a concern despite existing subsidies. Therefore, further support, such as subsidizing both the purchase and ongoing use of cold storage facilities, could help vendors reduce food spoilage and decrease the possibility of eating unsold foods.

Table 6: Ways Vendors Treated Spoiled or Non-Fresh Food

Means	Total	Vegetable	Animal	Fruits	Grain & oil
Sell spoiled or non-fresh products to customers at reduced prices	38.1	55.8	32.7	50.5	24.1
Dispose the food products at this shop	17.0	22.1	15.4	15.4	19.0
Dispose the food products at a dump site away from this shop	39.8	45.1	22.4	34.6	22.4
Recycled by supplier/producer	7.4	2.7	10.3	15.4	6.9
Consumed by our family or given to relatives	25.6	43.4	15.4	23.1	15.5
Almost no spoiled or non-fresh food	30.8	15.0	35.9	23.1	50.0
Other	9.9	8.0	10.9	7.7	6.9

Source: Calculated from the food vendor survey

Note: Shown figures are percentages of surveyed vendors

Access to Facilities, Business Time and Household Dietary Diversity

The estimation results show that access to cooling storage facilities is associated with longer business or working hours for vendors. In Model P1, where *dailyhour* is specified as the mediator, the coefficient of *ycooling* is 0.6823 and is statistically significant at the 5% level. The mean daily business hours for vendors with cooling storage is 12.21 hours, compared to 11.52 hours for those without cooling storage, suggesting that vendors with cooling storage facilities operate roughly 0.7 hours (about 40 minutes) longer per day than those without such facilities. Previous studies have indicated that the working hours of street or indoor food vendors are influenced by the types of food sold, as evidenced in South Africa (Sepadi & Nkosi, 2022). This study further revealed that access to food vending facilities is another factor affecting the length of working hours of food vendors in wet markets in China.

The estimation results also show that longer business time results in higher possibility of skipping meals. In the model where *yskip* is specified as the mediator, the coefficient of *dailyhour* is 0.1478 and is statistically significant at the 1% level. This indicates that a one-hour increase in daily business time (the variable *dailyhour*) increases the odds of skipping meals by approximately 15.9% ($e^{0.1478}$=1.1593), holding other variables constant.

The results further suggest that vendors skipping meals is associated with lower HDDS. The coefficient of the variable *yskip* is -0.0965 and is statistically significant at the 10% level. As mentioned above, meal skipping serves as a proxy for time constraints in food-related activities. The results indicate that skipping meals is associated with decreased household dietary diversity. Specifically, vendors who skip meals have approximately 9.2% lower expected household dietary diversity ($e^{-0.0965}$=0.9080), holding other variables constant.

Although the individual pathways of "*ycooling*→ dailyhour", "dailyhour→*yskip*", and "*yskip*→*hdds*" are statistically significant, the test results based on Model P1 indicate no statistically significant indirect effect along the path of "*ycooling* → *dailyhour*→ *yskip*→ *hdds*" (p= 0.199). That is to say, access to cooling storage facilities does not have a significant indirect effect on household dietary diversity through the combined mediating roles of business time (*dailyhour*) and skipping meals (*yskip*). The insignificant indirect coefficient suggests that time pressure may not be sufficiently high to exert a notable impact on the dietary diversity of migrant vendor households. One possible explanation relates to the household size of migrant food vendors in wet markets. Only 4.5% of surveyed vendors lived in single-person households. Most vendor households have multiple members: 31.5% have two members, 28.6% have three members, and 18.2% have four members, with roughly 60% having at least three members. Time pressure has been confirmed to be associated with household size (Douthitt, 2000). Unlike one-person households, larger households generally face fewer time constraints.

Moreover, according to the survey data, about 33% of migrant vendors report operating the business with family members or relatives, most commonly as a married or unmarried couple (88 out of 104 or 84.6%), accounting for about 28% of the full sample (312). This indicated that some food stalls or shops in wet markets are operated by two or more family members or relatives, which could also lessen time constraints on ensuring food security or household dietary diversity.

The food vendor paradox

This study examines how cold-storage sufficiency affects dietary diversity among migrant food vendors' households. More broadly, household dietary diversity varies across citywide households, food-delivery rider households, and migrant food-vendor households. The mean HDDS is 7.39 for citywide households, 4.89 for delivery rider households, and 4.79 for food vendor households (Table 7), indicating that food vendor households have the lowest level of dietary diversity. These results are consistent with findings from Kenya, where food vendors have also been reported to have lower dietary diversity (Demmler et al., 2024). Previous studies suggest that low dietary diversity is often associated with "food deserts" characterized by limited access to fresh and healthy foods (Odoms-Young et al., 2024). However, food vendors typically operate in environments with abundant food availability, which could be called a "food cornucopia". Despite this apparent advantage, food vendors within "food cornucopia" exhibit lower dietary diversity not only in China but also in other countries. This counterintuitive phenomenon can be conceptualized as a "food vendor paradox".

The "food vendor paradox" may be jointly determined by income, working conditions, and exposure to the food environment. Table 7 shows that the wages of delivery riders and the per capita net profit of migrant vendors in wet markets are lower than the per capita disposable income of urban households in Nanjing. This suggests that both groups have lower disposable incomes, which are associated with lower HDDS than those of urban households, even though both vendor and rider households likely have better food access. Therefore, income may be the primary factor driving the difference in HDDS, consistent with previous studies on HDDS determinants (French et al., 2019; French, Wall, & Mitchell, 2010).

Differences in exposure to the food environment may also play a role. Despite slightly lower incomes, food delivery riders have access to a greater diversity of food sources than migrant food vendor households. While food vendors are more intensively exposed to specific types of food, particularly fresh produce and cooked or ready-to-eat foods, delivery rider households report a higher number of food sources (mean = 3.56) than vendors' households (mean = 1.97). Broader access across multiple food sources may contribute to higher dietary diversity among riders.

Time constraints could also be an important factor. Food vendors work longer hours on average (11.86 hours) than delivery riders (9.49 hours), a difference of about 2.4 hours

Table 7: Comparing the HDDS of Three Groups of Households				
Household type	**Mean of HDDS**	**Estimated income per month**	**Time constraints**	**Exposure to food environment**
Citywide	7.39	6655 (disposable income per capita)	--	--
Delivery rider	4.89	6103 (income from delivery service)	9.49 hours	High exposure to ready-to-eat or cooked food
Migrant food vendor	4.79	6258 (business income per person)	11.86 hours	High exposure to fresh produce
Note: Disposable income per capita was calculated using data from the Nanjing Municipal Statistical Yearbook 2024. Other data were calculated from questionnaire surveys of citywide households, delivery riders and migrant food vendors conducted in 2022/2023 and 2024, respectively.				

per day. This longer workday may limit the time available for food-related activities and help explain the lower HDDS observed among vendor households. However, these interpretations require further empirical investigation in Nanjing and other locations in China and perhaps even elsewhere.

Conclusion

This study investigated the "unsold food" pathway linking access to food-retailing equipment, particularly insufficient cold storage facilities, to the dietary diversity of migrant food vendors' households in Nanjing. It found that greater access to cold storage facilities is associated with higher dietary diversity among these households, primarily by reducing the need to consume unsold food. In contrast, inadequate storage facilities increase reliance on unsold food, which is linked to lower household dietary diversity. However, no significant effect was observed along the "feeding time" pathway (i.e., "food facility⟶business time⟶feeding affair time⟶dietary diversity").

From a policy perspective, these results suggest that improving urban food security requires moving beyond improving food access alone to addressing infrastructural deficits in food systems, particularly in storage and energy provision. It is reasonable for the government to improve food vending facilities, especially by enhancing access to cold storage. Expanding the use of such equipment in wet markets could be facilitated by subsidizing both the purchase and operating costs (e.g., electricity) of cold storage, such as refrigerators. Promoting the use of an open-air cooler could also help maintain food freshness. Over the past three decades, municipal governments in Chinese cities such as Nanjing, Beijing, and Sanya have financially supported several rounds of wet market upgrading, which have significantly improved infrastructure (Zhong, Chen, & Zeng, 2022; Zhong et al., 2019). Building on these efforts, future rounds of upgrading should prioritize cold storage facilities or initiate a targeted wet market program focused on cold storage infrastructure.

This study contributes to the literature on urban food systems by shifting attention to an area largely overlooked in previous research: how insufficient market facilities affect unsold food, which in turn influences vendors' household dietary diversity. By revealing the hidden linkage between food retailing facilities and vendors' household dietary diversity, this study demonstrates that infrastructure not only affects vendors themselves (e.g., skipping meals) but also has implications for household-level nutrition. By identifying an 'infrastructural pathway' linking storage facilities to dietary outcomes through the management of unsold food, this study advances a novel mechanism through which urban food environments shape household nutrition. Moreover, this study highlights the substantial dietary diversity gap between vendor households and citywide households and calls for greater scholarly and policy attention to the "food vendor paradox". It contributes to the urban food security literature by demonstrating that participation in food provisioning does not necessarily translate into improved nutritional outcomes. It highlights that food system actors themselves may experience constrained dietary diversity, thereby challenging the conventional consumer-centric perspective in urban food security research.

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