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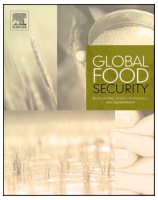

Consumer pesticide concerns and the choice of fruit and vegetable markets in five low- and middle-income countries

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ABSTRACT

Fruits and vegetables (FV) are critical components of nutritious and healthy diets, but there are growing concerns about food safety risks linked to their consumption. In this article, we explore consumers' concerns about pesticide-related food safety risks and how they relate to the choice of FV outlets, using survey data from 8644 consumers in five low- and middle-income countries (LMICs). Results show that pesticide residue is the most frequently cited source of food safety concern in each country, partly due to the intensive use of synthetic pesticides in FV production. We also find that FV retail environments are dominated by traditional open-air markets, despite the rapid growth and reach of modern retail outlets (e.g., supermarkets) in LMICs. Generally, consumers pay more attention to convenience and price when making FV purchase decisions, but pesticide-related food safety concerns also influence their FV outlet choices. Regression results of the associations between pesticide concerns and choice of FV outlets are heterogeneous across countries, but we find evidence suggesting that consumers who cited concerns with pesticides are more likely to demand FV from specialist shops and avoid purchasing from street hawkers. Our findings highlight the need to address pesticide risk concerns that can undermine consumer demand for nutritious foods, such as FV.

1. Introduction

It is widely recognized that fruits and vegetables (FV) are critical components of nutritious and healthy diets (WHO 2023). However, their consumption is low in many low- and middle-income countries (LMICs), with dire health consequences (Hall et al., 2009; Frank et al., 2019). For instance, in 2017, it was estimated that nearly 4 million deaths worldwide were attributable to inadequate FV consumption (WHO 2023). Market and non-market factors, including insufficient availability, high prices, poverty, weak preferences for certain healthy foods and food safety risks, may explain why the consumption of FV is low in LMICs (Liguori et al., 2022; FAO., IFAD., UNICEF., WFP., & WHO., 2023; Headey et al., 2023).

There are growing concerns about food safety hazards linked to the consumption of fresh FV (WHO 2012; Aworh 2021). Food safety is a "process or action that prevents food from containing substances that could harm a person's health" (FAO 2024), and it is closely interlinked with nutrition (Nordhagen et al., 2022; WHO 2022a). Unsafe food is associated with significant public health and economic costs. For instance, an estimated 600 million people fall ill (420,000 die) globally each year after eating contaminated food (WHO 2022a), with LMICs accounting for 53% and 75% of the foodborne illness and related deaths, respectively (Jaffee et al., 2019). This translates into annual productivity losses of about 95 billion USD and a public health burden of 110 billion USD for LMICs (Jaffee et al., 2019; WHO 2022a). Major food safety hazards include microbial pathogens, pesticide residues, heavy metals, naturally occurring toxins and adulterants (Jaffee et al., 2019; WHO 2022a). To minimize these risks, consumers may choose food

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markets where they have less concerns about food safety (Wertheim-Heck et al., 2014; Liguori et al., 2022).

In this paper, we examine whether pesticide-related food safety concerns influence consumers' choices of FV markets, using primary survey data from 8644 consumers in five LMICs: Bangladesh, Ghana, Kenya, Pakistan, and Uganda. We focus on pesticide-related food safety risks, given the sharply rising trend in pesticide use in LMICs (Shattuck et al., 2023). Increased use of pesticides and its potential consequences for human and ecological health, such as soil and water pollution, food contamination, and acute and chronic health problems, have been reported in Bangladesh (Khatun et al., 2023), Ghana (Ntow et al., 2006; Tambo et al., 2020), Kenya (Constantine et al., 2020), Pakistan (Rashid et al., 2022) and Uganda (Tambo et al., 2023).

While own production is important for many households in LMICs, it is not the main source of food (not even in rural settings) (FAO et al., 2023; Dzanku et al., 2024). Food markets play a significant role in improving nutrition and food safety (Koppmair et al., 2017; Jaffee et al., 2019; Matita et al., 2021). Food retail markets can provide easy access to nutritious foods (such as FV) and influence consumers' dietary preferences and choices. In LMICs, food markets include modern retailers (e.g., hypermarkets, supermarkets, specialist shops and convenience stores) and traditional outlets (e.g., open-air markets, roadside markets, kiosks and hawkers), with varying attributes, such as price, location, as well as type and quality of products and services offered (Lagerkvist et al., 2013; Khonje and Qaim 2019; Wanyama et al., 2019).

Urbanization and income growth have brought rapid changes in food systems and retail environments in many LMICs (FAO et al., 2023). Consequently, there has been a surge in interest in understanding consumer choice of food retail markets and demand for safe food in LMICs (e.g., Okello et al., 2012; Lagerkvist et al., 2013; Meng et al., 2014; Cheng et al., 2016; Khonje and Qaim 2019; Escobar-López et al., 2022; Dzudzor and Gerber 2023). One strand of the literature has examined how concerns about food safety influence consumer behaviours, including decisions on where to purchase food products (for a good review, see Liguori et al., 2022). We contribute to the literature by assessing consumers' concerns about food safety risks, attitudes toward pesticide use in FV production, and how pesticide concerns and socio-economic factors affect FV outlet choices. Insights gained from the study can be used to inform the design and implementation of food safety policies and strategies, such as the African Union's Food Safety Strategy for Africa 2022–2026 (African Union 2021).

Our analysis improves on previous studies in several aspects. First, in contrast to prior studies that provided qualitative evidence (e.g., Liguori et al., 2022), we provide quantitative evidence on the relationship between food safety concerns and retail market choices. Second, we examine the link between pesticide concerns and own production of FV, which is not trivial given the numerous policy initiatives and nutrition-sensitive interventions encouraging own food production or home gardening for improved food and nutrition security in LMICs (Schreinemachers et al., 2015; Olabisi et al., 2021). Third, most previous empirical studies on consumer food outlet choices were based on data from one country or small geographic areas in a country (e.g., Okello et al., 2012; Meng et al., 2014; Khonje and Qaim 2019; Dzudzor and Gerber 2023), which limits the external validity of the findings. By contrast, we use consumer survey data from five LMICs, which allow us to draw some broader conclusions. Finally, the growing body of literature on consumer food purchase behaviours has largely focused on urban populations, although diet transition (from home-produced foods to market-purchased products) is also increasingly occurring in rural areas (FAO et al., 2023). We address this gap by using consumer data from rural, peri-urban and urban environments.

2. Data and methods

2.1. Data

We used cross-sectional survey data collected from 8644 FV consumers in five LMICs. The countries include Ghana (West Africa); Kenya and Uganda (East Africa); and Bangladesh and Pakistan (South Asia). Thus, our sample includes consumers from a diverse range of food environments in LMICs. The surveys were conducted between 2021 and 2023 with the primary aim of understanding food safety concerns and practices among LMIC consumers.

A multi-stage sampling technique was used to select the respondent for the study. In the first stage, we purposively selected locations with high FV production and marketing activities, based on information from the Ministry of Agriculture in the study countries. In Bangladesh, Pakistan and Uganda, the surveys covered all the administrative divisions, provinces and regions of the country, respectively. The surveys were also conducted across nine of the 16 administrative regions of Ghana, and eight of the 47 counties in Kenya. In the second stage, districts with major FV production areas and marketing centres were selected and stratified into urban, peri-urban and rural settings. Finally, within each district, we randomly sampled and interviewed producers, traders and end-consumers of FV.[1] The interviewed consumers (household heads or spouses) were the primary household decision-makers on the production, sale or purchase of FV.

The number of respondents interviewed across the study locations in the respective countries are presented in Table A1 in the Supplementary Material, while the distribution of the sample by area of residence (urban, peri-urban or rural) and respondent type (producer, trader or end-consumer) are shown in Table 1. Overall, 1656, 1634, 1938, 1839 and 1577 FV consumers were interviewed in Bangladesh, Ghana, Kenya, Pakistan and Uganda, respectively. In each country, the interviews were conducted face-to-face by a team of about 15 local enumerators using questionnaires that were configured on Open Data Kit software. The questionnaires included sections on consumer demographic characteristics, food consumption patterns and purchase behaviour, food safety awareness and concerns, pesticide risks and safety concerns, and pesticide use practices in FV production.[2]

2.2. Estimation methods

We used descriptive statistics to summarize consumers' attitudes and concerns towards pesticide-related food safety issues, and their choice of FV outlets. Consumers in LMICs tend to use multiple retail outlets for their FV purchases, including modern outlets (such as supermarkets and specialist shops) and traditional outlets (e.g., street hawkers and open-air and roadside markets) (Okello et al., 2012; Lagerkvist et al., 2013; Wanyama et al., 2019). The choice of a specific FV outlet is a binary variable that can be estimated using binary response models, such as logit and probit. However, such binary response models will ignore the interrelationships between the different FV outlets, potentially leading to biased regression estimates. Hence, we analyse the relationship between consumer pesticide concerns and the choice of FV outlets using a multivariate probit (MVP) model.

The MVP model estimates the effects of a set of covariates (including pesticide concerns) on consumers' choice of FV outlets simultaneously, while allowing for the possibility that the choice of any particular FV outlet could be correlated with other FV outlet choices (Greene 2019). Following Cappellari and Jenkins (2003), the MVP model can be

[1] We generally refer to producers, traders and end-consumers of FV as consumers, given that their households consume FV from several sources, including own farms, own shops and purchases from retail outlets.

[2] The questionnaires and datasets used are available from the authors upon request.

Table 1
Respondents' characteristics.

Variable	Description	Bangladesh (n = 1656)	Ghana (n = 1634)	Kenya (n = 1938)	Pakistan (n = 1839)	Uganda (n = 1577)
Age	Age of respondent (years)	42.9 (12.30)	42.6 (12.25)	43.56 (13.42)	40.81 (12.40)	38.51 (12.85)
Male	Male respondent (1/0)	0.69	0.42	0.46	0.78	0.37
Education	Respondent has at least secondary level of education (1/0)	0.45	0.33	0.52	0.46	0.34
Household size	Number of household members (#)	4.95 (2.00)	5.82 (3.24)	4.62 (2.10)	7.14 (2.34)	5.78 (2.72)
Monthly income (<$100)	Monthly household income is < 100 USD (1/0)	0.08	0.52	0.34	0.40	0.12
Monthly income ($100–200)	Monthly household income is 100–200 USD (1/0)	0.50	0.32	0.53	0.43	0.53
Monthly income (>$200)	Monthly household income is > 200 USD (1/0)	0.42	0.16	0.13	0.17	0.35
Producer	Respondent is a producer and consumer of FV (1/0)	0.34	0.36	0.38	0.17	0.35
Trader	Respondent is a trader and consumer of FV (1/0)	0.13	0.24	0.30	0.41	0.17
End-consumer	Respondent is an end-consumer of FV (1/0)	0.57	0.40	0.32	0.42	0.48
Food safety information	Received information on food safety (1/0)	0.70	0.74	0.61	0.34	0.45
Foodborne illness	Household who perceived having experienced foodborne illness from consuming FV (1/0)	0.30	0.29	0.23	0.43	0.29
Urban area	Respondent resides in an urban area (1/0)	0.22	0.41	0.15	0.49	0.30
Peri-urban area	Respondent resides in a peri-urban area (1/0)	0.16	0.24	0.36	–	0.23
Rural area	Respondent resides in a rural area (1/0)	0.62	0.35	0.49	0.51	0.47

Note: Numbers in parentheses are standard deviations. HH=Household.

specified as:

$$y^*_{imk} = \alpha_0 + \alpha_1 PC_{imk} + \boldsymbol{\alpha_2 X_{imk}} + \boldsymbol{\varepsilon_{imk}}; m = 1, 2, \ldots, n$$

$$y_{imk} = 1 \text{ if } y^*_{imk} > 0 \text{ and 0 otherwise}$$

where y^*_{imk} represents consumer i's latent propensity to use FV outlet m in country k, and y_{imk} denotes the actual use of FV outlet m by consumer i in country k in the week prior to the survey. *PC* is a dummy variable that is equal to 1 if the consumer expressed food safety concerns related to pesticide residues, and zero otherwise. Thus, α_1 is the main coefficient of interest, and it computes the correlations between consumer pesticide concerns and the various sources of FV. $\boldsymbol{X}$ is the vector of other covariates, with $\boldsymbol{\alpha_2}$ being the associated parameters to be estimated. $\boldsymbol{\varepsilon}$ is a vector of error terms distributed as multivariate normal.

The covariates ($\boldsymbol{X}$) include age, sex, educational level of the consumer, household size and income, type of respondent (i.e., producer, trader or end-consumer), access to food safety information, food poisoning incidents and location variables (Table 2). The choice of these control variables was informed by literature on consumer choice of food markets (e.g., Li and Houston 2001; Okello et al., 2012; Khonje and Qaim 2019). It should be mentioned that we are not attempting to show causal relationships between the covariates and the choice of FV retail outlets, given that several of the covariates, including pesticide concern, are potentially endogenous variables. Thus, the MVP model results are correlations, and we have interpreted them as such. The country-specific MVP models were estimated in Stata using the conditional mixed-process estimator (Roodman 2011).

3. Results and discussions

In this section, we first present descriptive statistics describing the consumers in our sample and their choices of FV outlets, followed by results on the consumers' concerns and attitudes towards food safety risks in general and specifically pesticides. We then present our main empirical results on the relationship between pesticide concerns and FV outlet choices, based on MVP regression analyses.

3.1. Sample characteristics

Table 1 compares the characteristics of the surveyed consumers across the five study countries. Our sample consists of middle-aged respondents, with an average age of between 39 and 44 years. Average household sizes range from about 5 in Bangladesh and Kenya to 7 in Pakistan. The respondents have attained limited level of education, particularly in Ghana and Uganda where only about a third of them have had at least secondary education. The average monthly household income of a majority of the respondents is between 100 and 200 USD. Proportionally more of the Asian respondents earn higher monthly household incomes than their African counterparts. On average, only 56% of the respondents reported having received information on food safety. It is worse in Pakistan and Uganda, where less than half of the respondents have been exposed to food safety information. The main sources of food safety information include radio and television broadcasts, internet, family and friends, and public health officials. The percentages of respondents whose household members have reportedly experienced food poisoning symptoms (such as diarrhoea, vomiting, nausea, abdominal cramps and fever) after consuming FV vary from 23% in Kenya to 43% in Pakistan. Thus, food poisoning incidents associated with FV consumption seem to be more common in Pakistan, compared to the other four countries. Consumers from urban, peri-urban and rural areas made up 32%, 20% and 48% of the sample, respectively.

3.2. Choice of FV outlets

The main FV sources used by the consumers are shown in Fig. 1. Local open-air markets are the most commonly used source of FV in almost all the study countries. This finding lends support to earlier observations that traditional open-air markets remain a major food outlet in LMICs, despite the rapid growth of modern retail markets (Meng et al., 2014; Dzudzor and Gerber 2023). Own production is also important, particularly in Uganda where nearly three-quarters of the consumers cited it as one of their key sources of FV, mainly traditional vegetables. The use of on-farm markets is more popular in Bangladesh where about 70% of the consumers purchase FV directly from farms.

Very few consumers depend on supermarkets for FV, particularly in the three African countries. For instance, in Kenya where there has been a rapid spread of supermarkets in recent decades (Neven and Reardon 2004; Rischke et al., 2015), only a paltry 1% of the consumers mentioned supermarkets as their main FV outlet. One plausible explanation is that supermarkets that offer fresh FV are mostly found in urban cities (Rischke et al., 2015), whereas about half of the consumers in our

Table 2
Food safety issues of most concern[a].

	Bangladesh (n = 1656)	Ghana (n = 1634)	Kenya (n = 1938)	Pakistan (n = 1839)	Uganda (n = 1577)	All (n = 8644)
Microbial food poisoning	73.37	39.29	29.36	35.56	26.89	40.54
Heavy metal contamination	64.13	25.83	11.46	13.05	9.07	24.17
Pesticide residues	75.00	65.85	58.62	45.68	53.09	59.42
Mycotoxins	15.94	5.69	19.5	12.51	24.10	15.56
Genetically modified foods	24.34	4.35	14.81	3.81	21.62	13.56
Food additives	61.41	45.29	20.18	9.84	19.59	30.52
Hormones/steroids/antibiotics	30.80	2.57	13.57	3.75	4.88	11.12

Numbers are percentages of consumers who expressed concerns with the various food safety hazards.
[a] These are general food safety concerns and not specifically for FVs. Multiple responses permitted.

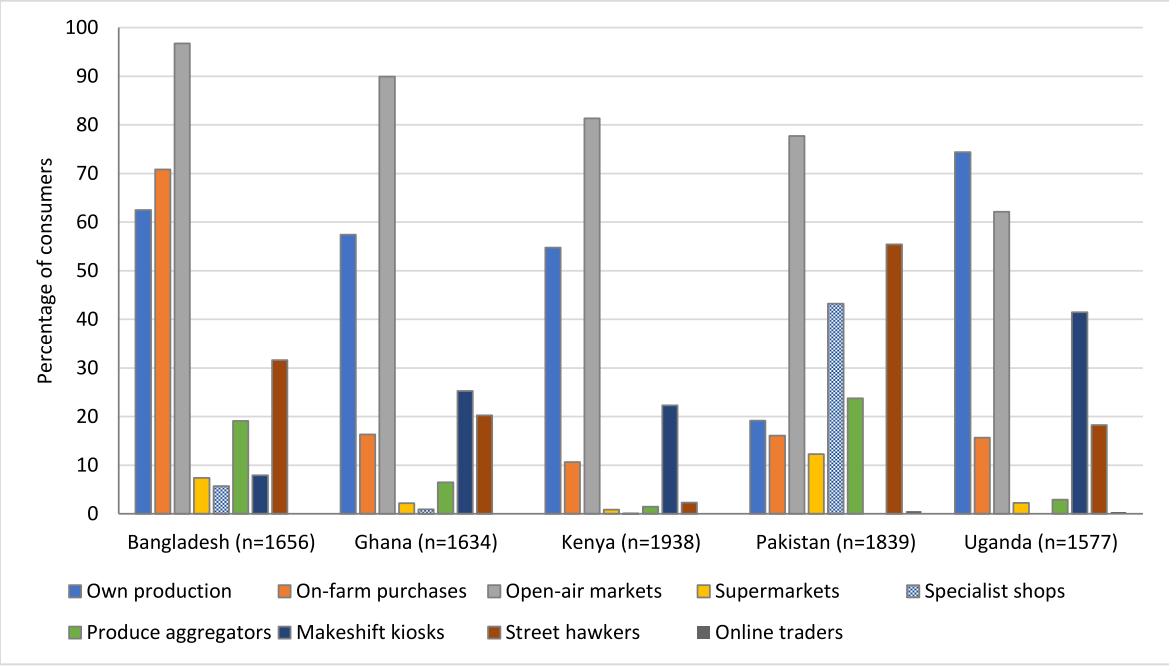

Fig. 1. Main outlets where consumers source their FV (multiple responses permitted).

sample reside in rural areas. However, this is unlikely the case because a large majority of the urban consumers in our sample also do not buy FV from supermarkets. Our results resonate with Wanyama et al. (2019), who found that none of their sample households in Kenya and Uganda purchased FV from supermarkets.

Shops that deal primarily in FV (i.e., specialist shops or greengrocers) are an important outlet in Pakistan (43%) and to a little extent in Bangladesh (6%) but not really in the three African countries. Similarly, produce aggregators or brokers (i.e., individuals or organizations that collect farm produce from multiple farmers for distribution and sale) are slightly more commonly used as FV outlets among Asian consumers than their counterparts in Africa. Two other important traditional FV retail outlets besides open-air markets are makeshift kiosks along busy roads and street hawkers. The results suggest that street hawkers are more popular than makeshift kiosks as FV outlets among consumers in Asia, while the opposite is true for consumers in Africa. The share of consumers in our sample who use online food delivery services for their FV are negligible (<0.5%), suggesting that the FV markets in these countries are yet to take advantage of the ongoing home food delivery revolution (Meemken et al., 2022).

Fig. 2 illustrates the key factors that consumers reportedly consider when deciding on the choice of FV retail outlets.[3] Proximity to home or workplace (i.e., physical access) is the most cited reason for selecting a particular FV purchasing point. Previous studies have reported a similar finding in Kenya (Lagerkvist et al., 2013), Bangladesh (Snoek et al., 2021), and Ghana (Dzudzor and Gerber 2023). Lower retail prices are also an important consideration for about half of the consumers in each country. The importance of distance and price in FV purchase decisions of consumers may partly explain the relatively high use of traditional open-air markets than modern retail outlets such as supermarkets, as the former are more ubiquitous and offer cheaper FV prices in low-income countries (Gómez and Ricketts, 2013; Wanyama et al., 2019). Strikingly, less than a quarter of the sampled consumers in Africa pay particular attention to produce quality and safety when making decisions on the choice of FV outlets, as compared to about half of the sample of Asian consumers. Given the less importance consumers in Africa give to safety and quality attributes when choosing FV retail outlets, it is not surprising that very few of them buy their FV from supermarkets, which are perceived to be associated with the sale of high-quality and safer food products (Neven and Readon 2004; Lagerkvist et al., 2013; Liguori et al., 2022).

Other factors that some of the consumers reportedly consider when

[3] Unfortunately, the datasets preclude us from exploring the reasons for consumers' selection of specific FV outlets.

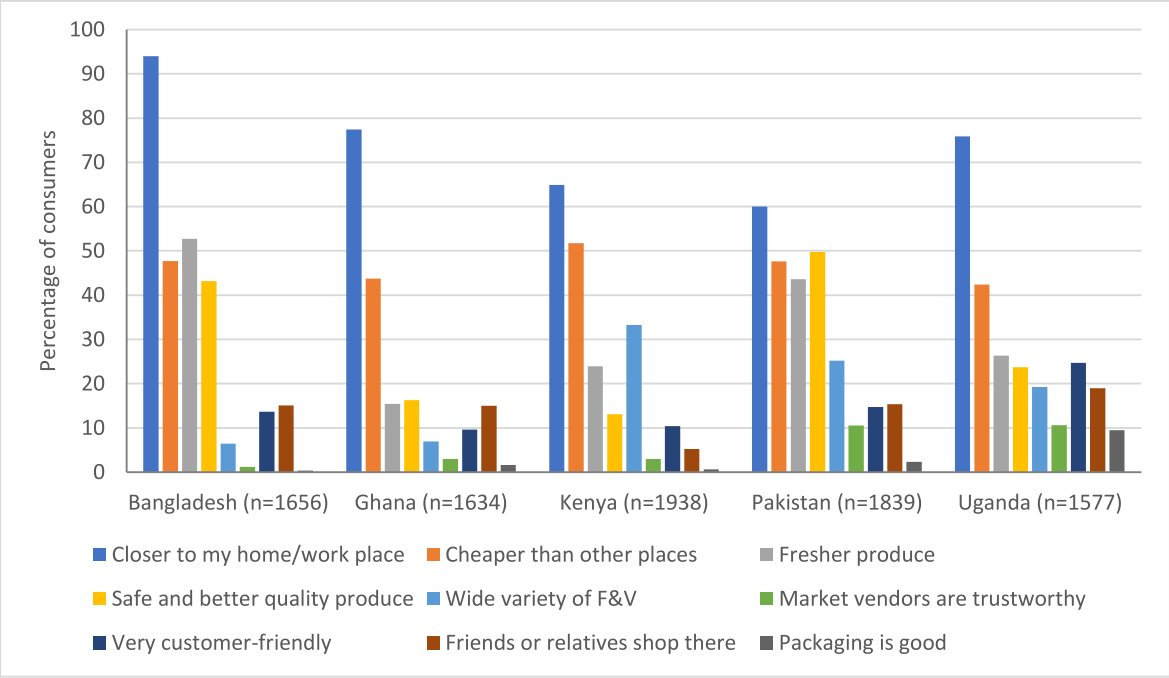

Fig. 2. Main reasons for selecting the place for purchasing FV.
Note: Multiple responses permitted.

deciding on their FV outlets include the freshness and variety of produce sold, the quality of services offered by the retail outlet, and whether friends, neighbours and families shop there (peer effects). A noticeable observation from Fig. 2 is that roughly half of the consumers in the two Asian countries value price, fresher produce and safety and quality standards in addition to convenience, while most of the consumers in the three African countries pay attention to mostly convenience and price factors when deciding on their FV retail outlets.

3.3. *Food safety concerns and behaviours*

Table 2 reports the food safety issues of most concern to FV consumers in the five study countries.[4] We find that a larger share of consumers in Bangladesh expressed concerns about food safety issues than their counterparts in Ghana, Kenya, Pakistan and Uganda. For instance, nearly or more than two-thirds of the Bangladeshi consumers raised concerns about microbial food poisoning, heavy metal contamination and food additives, while less than half of the consumers in the other countries expressed such concerns. This is not surprising, given that Bangladesh is a densely populated country with a high prevalence of food safety incidents (Snoek et al., 2021; Islam et al., 2023). Overall, only 3% of the respondents in Bangladesh expressed no concern about food safety issues, as compared to about 15% each in the three African countries and 21% in Pakistan.

On average, only about 14% of the respondents expressed safety concerns about genetically modified (GM) foods, which is consistent with some evidence that consumers in LMICs have generally positive attitudes towards GM foods (Li et al., 2002; Krishna and Qaim 2008). This is possibly because of a lack of awareness or limited or no availability of GM crops in the study countries. Similarly, less than a quarter of the total sample of consumers were worried about food contaminated by mycotoxins, heavy metals and hormones, steroids or antibiotics.

Pesticide contamination is the most cited food safety concern in all the five countries, but with considerable variation across countries. For example, less than half of the Pakistani consumers seemed to care about pesticide contamination, compared to three-quarters of consumers in the other Asian country (Bangladesh). Overall, almost 60% of the consumers in our sample have pesticide-related food safety concerns. This corroborates previous research showing that pesticide residue is a frequent source of food safety concern for consumers (Bruhn et al., 1991; Cheng et al., 2016).

Fig. 3 gives some indications as to why pesticide contamination is among the most mentioned food safety concerns in all the study countries. The results show that chemical pesticides are the most widely used pest control method. The share of FV farmers who opts for chemical pest control range from 77% in Kenya to over 90% in Bangladesh, Ghana and Pakistan. Fig. 4 suggests that chemical pesticides are used intensively in FV production. Roughly half of the sample farmers reportedly spray pesticides weekly in their FV farms. It is more common in Bangladesh where more than a quarter of the farmers tend to spray pesticides every 2–3 days per season to control pests of FV, mainly chili, eggplant, gourd and papaya. The intensification of pesticide use in FV production, particularly in Bangladesh, has been widely reported in the literature (de Bon et al., 2014; Khatun et al., 2023).

It should be mentioned that the use of pesticides is not necessarily bad. Pesticides are important for reducing pest-induced crop losses, increasing agricultural productivity and promoting food security (Popp et al., 2013; Sheahan et al., 2017; WHO 2022b). However, intensive and indiscriminate use of pesticides can be harmful to human and environmental health (Kaur et al., 2024). Hence, farmers are encouraged to adopt integrated pest management (IPM) approaches, which involve the use of a combination of pest management techniques (such as biological, cultural, physical, and chemical methods), thereby reducing the need to spray chemical pesticides. However, the use of non-chemical IPM methods is very low among the farmers in our sample (Fig. 3). In all the countries (except Bangladesh), less than 10% of the farmers apply botanical pesticides or biological control methods, which are safer and eco-friendly pest control options. In addition, only a few farmers used preventive cultural methods (e.g., crop rotation and field sanitation) and

[4] A disaggregation of the food safety concerns according to the respondent type (i.e., farmers, traders and consumers) is presented in Table A2 in the Supplementary Material.

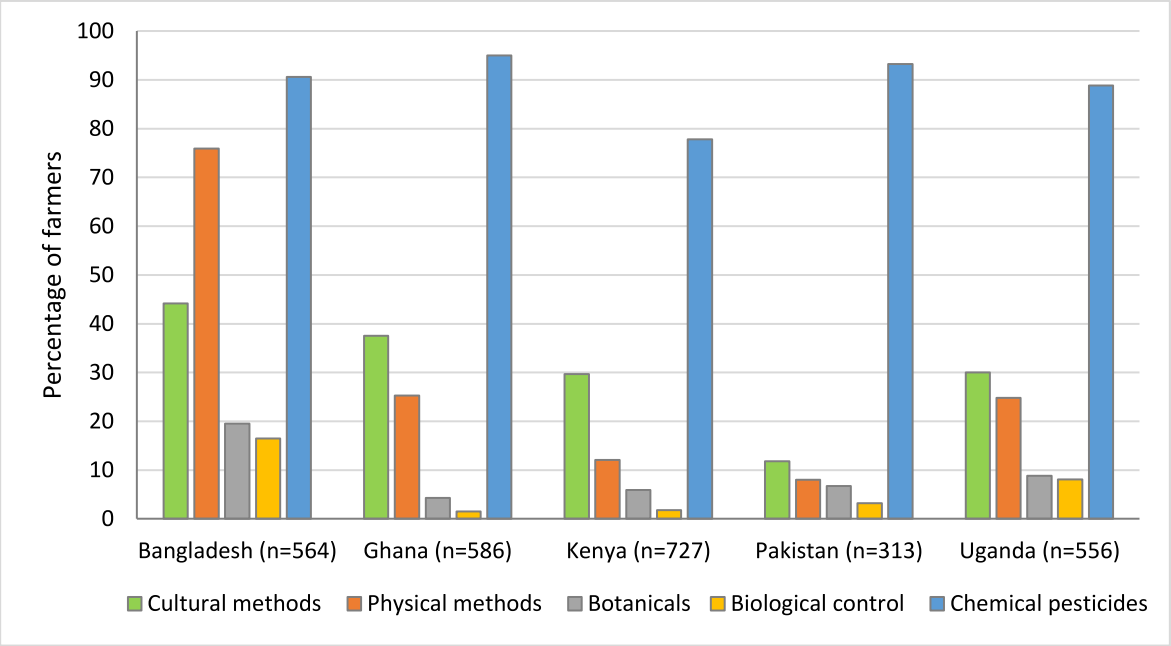

Fig. 3. Pest management practices used by farmers (multiple responses permitted).
Note: Cultural methods include timely planting, field sanitation, intercropping, crop rotation and trap cropping. Physical methods include handpicking of pests and destruction of infested plants. Botanicals include natural plant derivatives or extracts (such as neem and pyrethrum), while biological control involves the use of natural enemies, such as predators and parasitoids. Chemical control relates to the use of synthetic pesticides.

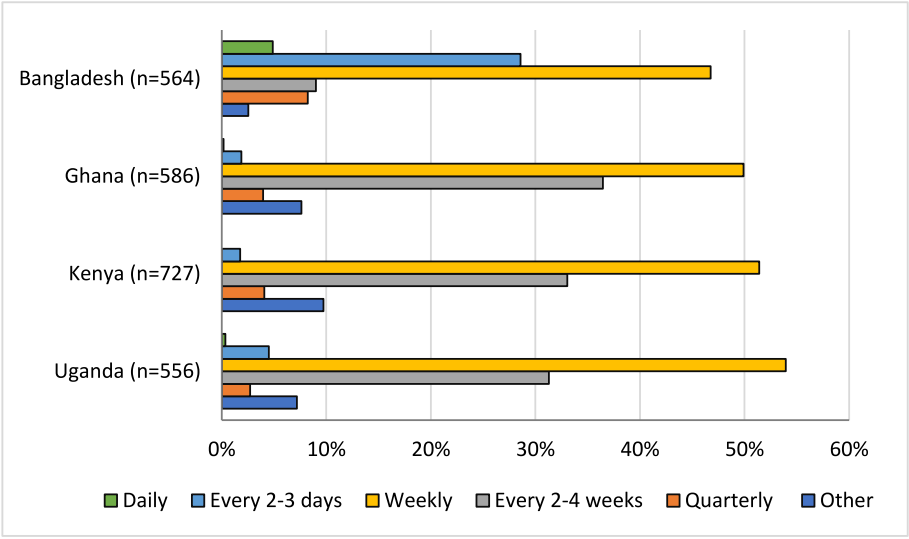

Fig. 4. Frequency of pesticide sprays per season[5]
[5]The results for Pakistan are not reported in Fig. 4 because the responses were phrased differently. In Pakistan, 20%, 34%, 28% and 18% of the farmers reportedly spray pesticides 1–2 times, 3–4 times, 5–6 times and more than 6 times respectively per season.

physical control methods, such as handpicking of pests. This is particularly true for Pakistan where most of the FV farmers rely exclusively on chemical pesticides for pest control. The limited use of IPM strategies in LMICs has been attributed to several obstacles, including lack of access to information about IPM, insufficient technical support to farmers, weak adoption incentives, lack of favourable government policies and pesticide industry influence (Parsa et al., 2014; Alwang et al., 2019; Tambo and Liverpool-Tasie 2024).

Table 3 presents the consumers' responses to some questions related to pesticide risks. We find that only a small percentage of consumers (especially in Ghana and Pakistan) reportedly buy organic produce to ensure that they consume pesticide-free food. When asked about reasons for not consuming organic FV, the consumers cited lack of knowledge about organic products and where to get them, unavailability in local grocery stores, higher prices, and lack of trust that they are indeed organic products. Only 13% of consumers in Pakistan perceive that they are likely to buy food that is labelled certified pesticide-free, compared to 57% in Bangladesh and Kenya. Overall, approximately 60% of the surveyed consumers have no intention of buying certified pesticide-free products. As shown in Table 2, almost 40% of the consumers are not concerned about pesticide residues; hence, this may partly explain their lack of desire to purchase pesticide-free food products. It is possible that the consumers do not trust pesticide-free labels, given previous research showing some level of distrust in certain food labels among consumers in

Table 3
Consumers' attitudes toward pesticide risks.

Attitudes toward pesticides	Bangladesh (n = 1656)	Ghana (n = 1634)	Kenya (n = 1938)	Pakistan (n = 1839)	Uganda (n = 1577)
1. I buy organic food to ensure that my food does not contain pesticides (% agree)	42.70	18.72	35.66	12.74	34.56
2. Pesticide film on fruits and vegetables increases their shelf life (% agree)	46.50	21.73	34.52	36.96	60.94
3. I am more likely to buy food that is labelled 'certified pesticide-free' (% agree)	57.06	41.92	56.66	13.28	33.67
4. More information is needed to explain pesticides used on food (% agree)	73.73	77.42	95.51	77.36	91.76

LMICs (Kikulwe et al., 2014; Ha et al., 2019; Wang et al., 2020).

Some of the consumers (ranging from 22% in Ghana to 61% in Uganda) perceive that pesticide film on FV can enhance their shelf life, which is worrying. A recent study in Uganda has shown that 95% of consumers in their sample buy tomatoes that are stained with pesticide residues, despite knowing the potential health risks (Sekabojja et al., 2023). There is an urgent need to address this perception, given that pesticide residues in food can cause serious health problems when they exceed maximum residue levels (WHO 2022b). A large majority of consumers in the five countries agree that more pesticide-related information is needed. This view was particularly strong among consumers in the two East African countries. Thus, information campaigns would be necessary to educate consumers on pesticide risks and safety precautions, such as peeling or washing FVs, which can help limit the intake of pesticide residues (WHO 2022b). Previous studies have shown that information interventions can contribute to improved knowledge of pesticide risks and safety measures (Goeb and Lupi 2021; Tambo et al., 2023).

3.4. Association between pesticide concerns and choice of FV outlets

The MVP estimates of the relationship between consumer pesticide concerns and the choice of FV outlets are summarized in Table 4. We find a statistically significant correlation between pesticide concerns and own FV production in two countries. Specifically, consumers who expressed pesticide-related food safety concerns are about 3 and 15 percentage points more likely to grow their own FV (especially vegetables) in Bangladesh and Ghana, respectively. This suggests that in certain contexts, raising awareness about pesticide risks can potentially encourage home-based vegetable production, which can contribute to improved nutrition (Schreinemachers et al., 2015). This finding is consistent with evidence that food safety concerns have provided a strong motivation for urban households to grow their own vegetables in certain contexts (Kendall et al., 2019; Pham and Turner 2020).

In Ghana and Kenya, having concerns about pesticides is significantly related to an increase in the use of on-farm markets. Conversely, there is a negative correlation between consumer concerns about pesticides and on-farm purchases of FV in Pakistan and Uganda. Previous research has shown that consumers source food directly from local producers where they have less pesticide-related concerns (Liguori et al., 2022). Hence, the mixed evidence on the relationship between pesticide concerns and on-farm purchases of FV may be reflective of how consumers perceive the safety of FV produced by farmers in their localities.

Results further show that consumers with pesticide-related food safety concerns are more likely to avoid buying FV from open-air markets in Bangladesh and Uganda, but their counterparts in Kenya and Pakistan are less likely to share this behaviour. Bangladeshi consumers who expressed concerns about pesticides have 11 and 16 percentage points greater likelihood of buying FV from supermarkets and specialist shops, respectively. Similarly, pesticide concerns significantly increase the probability of consumers' purchasing FV from specialist shops in Pakistan by 8 percentage points. Thus, we find evidence that pesticide risk perceptions influence consumers' decision to demand FV from specialist shops in the two Asian countries. This is possibly due to a general perception that FV from specialist shops are safer (Lagerkvist et al., 2013; Okello et al., 2012).

The probability of buying FV from produce aggregators reduces by about 3 and 28 percentage points respectively in Ghana and Bangladesh if consumers are concerned about pesticide residues. Similarly,

Table 4
Summary of the relationship between pesticide concerns and FV outlet choices.

	Own production	On-farm purchases	Open-air markets	Super-markets	Specialist shops	Produce aggregators	Makeshift Kiosks	Street hawkers
Bangladesh	0.030***	0.004	−0.00003***	0.108***	0.161***	−0.276***	0.008	−0.039**
	(0.009)	(0.006)	(0.00001)	(0.014)	(0.014)	(0.022)	(0.024)	(0.019)
Ghana	0.146***	0.054***	−0.006	–	–	−0.026**	−0.170***	−0.144***
	(0.021)	(0.020)	(0.016)			(0.012)	(0.020)	(0.019)
Kenya	0.021	0.031**	0.045***	–	–	–	−0.041**	−0.011*
	(0.018)	(0.014)	(0.017)				(0.019)	(0.006)
Pakistan	−0.016	−0.039**	0.047**	−0.013	0.077***	−0.008	–	0.008
	(0.015)	(0.017)	(0.020)	(0.015)	(0.023)	(0.018)		(0.023)
Uganda	−0.022	−0.065***	−0.053**	–	–	–	0.075***	−0.044**
	(0.020)	(0.019)	(0.023)				(0.024)	(0.019)

Note: ***p < 0.01, **p < 0.05, *p < 0.1. Each row are results from a country-specific MVP regression analysis. Marginal effects reported. Numbers in parentheses are standard errors.
The full regression results can be found in Tables A3 to A7 in the Supplementary Material.

consumers with concerns about pesticides in Kenya and Ghana have 4 and 17 percentage points lower likelihoods of doing their FV purchases from makeshift kiosks. On the contrary, concerns about pesticides in Uganda increase the choice of kiosks for FV by almost 8 percentage points. Finally, the results demonstrate that that a consumer who is concerned about pesticide contamination is significantly less likely to purchase FV from street hawkers in four of our study countries. This is reasonable, as street hawkers are perceived to sell low-quality food products (Meng et al., 2014).

In summary, the relationships between consumer pesticide concerns and the choice of various modern and traditional FV outlets are heterogeneous across different food environments in LMICs. Nonetheless, we find consistent evidence suggesting that where consumers are concerned about pesticide residues, they are likely to rely less on street hawkers and increase the use of specialist shops for FV.

3.5. Other determinants of FV market choices

The results in Tables A3 to A7 in the Supplementary Material show other significant drivers of consumer choice of FV outlets, and we highlight a few of them in this section. In the three African countries, age is significantly and positively correlated with own production, meaning that older consumers are more likely than younger consumers to produce FV for home consumption. This could be due to differences in access to resources (such as land and capital) and willingness to farm. Female consumers in Bangladesh and Uganda are 2 and 6 percentage points less likely than their male counterparts to grow their own FV. This may be related to the well-documented gender gaps in agricultural decision-making and access to productive inputs (Kristjanson et al., 2017).

In all the countries (except Ghana), having a larger household size increases the likelihood that a consumer will rely on self-produced FV, perhaps due to family labour availability for farm activities or a higher household demand for FV and thus an incentive to substitute purchased FV with own production to reduce household food expenditure. Contrary to previous arguments (Liguori et al., 2022), we did not find evidence that low-income consumers are more likely to shop in traditional food markets. Our results from the two Asian countries also depart from evidence from Africa showing that the likelihood of using supermarkets increases with rising income (Okello et al., 2012; Meng et al., 2014; Khonje and Qaim 2019). As expected, farming households have a higher probability of consuming home-produced FV, compared to traders and end-consumers.

In Bangladesh and Ghana, exposure to food safety information negatively correlates with the propensity to purchase FV from street hawkers, whereas it positively correlates with own-production and on-farm purchases of FV. Similarly, Kenyan consumers with access to food safety information are more likely to obtain FV from their own or other farms. In Pakistan, where incidence of foodborne illness is slightly higher (see Table 1), consumers who perceived that their household members have ever suffered food poisoning symptoms from FV consumption are more likely to grow their own vegetables or depend on supermarkets and specialist shops, but they are less likely to buy FV directly from farmers. In Bangladesh, past experience with foodborne illness increases the likelihood of sourcing FV from own or other farms and reduces the likelihood of purchasing FV from most retail outlets. The results also show that rural consumers in three countries (Bangladesh, Kenya and Uganda) are more likely than urban consumers to purchase FV directly from farmers' fields, which is presumably because of closer proximity to local farmers. Moreover, in all the five countries, consumers in rural areas are more likely than their urban counterparts to obtain FV from own farms. This is consistent with expectations because increasing urbanization is resulting in loss of lands and natural capital needed for agricultural production (FAO et al., 2023).

4. Conclusions

In this paper, we used survey data from three African countries (Ghana, Kenya and Uganda) and two Asian countries (Bangladesh and Pakistan) to explore consumers' concerns about food safety, with particular focus on pesticide risks and how they relate to the choice of FV outlets. Results showed that pesticides are the most cited source of food safety concerns, followed by microbial food poisoning and food additives. The high concerns about pesticide residues could be due to several factors, including the intensive use of synthetic pesticides and the low adoption of non-chemical pest management strategies (such as cultural, physical and biological control) among FV farmers in the study countries, consumer perception of pesticide risk relative to other food safety risks, as well as marketing and media campaigns. We also found evidence suggesting that despite the reportedly rapid growth and reach of modern retail outlets (e.g., supermarkets) in LMICs, the FV retail sector is still dominated by traditional open-air markets because they offer lower prices, product diversity and convenience to consumers. Own production of FV is also quite common among consumers in all the countries, except Pakistan.

Further descriptive analysis showed that in general, consumers usually pay more attention to convenience and price than produce quality and safety when making decisions on the choice of FV outlets. Nonetheless, results from multivariate probit regressions demonstrated that pesticide-related food safety concerns are statistically significant determinants of consumer choice of specific FV outlets. For example, consumers who cited concerns with pesticides are 8–16 percentage points more likely to demand FV from specialist shops and 1–14 percentage points more likely to avoid purchasing FV from street hawkers. However, the estimated associations between pesticide concerns and choice of FV outlets are generally heterogeneous across countries. For instance, consumers with pesticide concerns exhibited higher likelihoods of growing own FV in Bangladesh and Ghana, higher (lower) likelihoods of using on-farm markets in Ghana and Kenya (Pakistan and Uganda), and lower probabilities of buying FV from makeshift kiosks in Ghana and Kenya. The regression results further showed that the choice of FV outlets is significantly correlated with consumer demographic characteristics, access to food safety information and prior experience with foodborne illness, albeit with differential effects across the study countries.

Several implications emerge from these findings. First, given the high prevalence of malnutrition in LMICs (FAO et al., 2023), pesticide risk concerns that can undermine consumer demand for nutritious foods, such as FV, deserve serious policy attention. In view of the importance of market access for improved nutritional outcomes (Koppmair et al., 2017; Matita et al., 2021), there is a need to address consumer food safety concerns that discourage the use of certain FV markets. Incentivizing farmers to adopt sustainable pest control strategies, such as IPM, can help reduce the reliance on synthetic pesticides and increase the supply of safer FV to various markets. In addition, enforcement of pesticide safety regulations and monitoring can promote food safety in the FV supply chain. There is also a need to sensitize consumers about food safety-related pesticide risks through public awareness campaigns, which may drive the demand for safer FV, and in turn nudge farmers and traders to supply them.

It should be mentioned that while this study has focused on pesticide-related food safety risks, microbial pathogens (e.g., *Campylobacter* spp., *Escherichia coli*, norovirus and *Salmonella* spp.) and macroparasites (helminths) account for a large proportion (>80%) of the foodborne disease burden in LMICs (Jaffee et al., 2019). Hence, it is critically important to recognize these major causes of foodborne illnesses in efforts to improve food safety in LMICs. Attention should also be paid to the low levels of consumer concerns for other food safety hazards, such as mycotoxins, heavy metal contamination, hormones and antibiotics, which can also have detrimental effects on human health.

For future research, it would be useful to investigate the causal

relationships between consumer pesticide concerns and food market choices and compare the results with our findings. It also important to establish pesticide residue levels in various markets to confirm the risks and critical control points. Finally, while the current study has focused on how pesticide concerns affect where consumers purchase FV, concerns about pesticides can influence other consumer behaviours, including food preparation and storage practices, eating out of home behaviours, and the nutritional quality of diets consumed (Liguori et al., 2022), which can be explored in future studies.

CRediT authorship contribution statement

Justice A. Tambo: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Monica K. Kansiime:** Writing – review & editing, Project administration, Data curation, Conceptualization. **Jayanthi R. Alaganthiran:** Writing – review & editing, Validation, Data curation. **Muhammad Danish:** Validation, Investigation, Data curation. **Solomon A. Duah:** Validation, Investigation, Data curation. **Shah Faisal:** Validation, Investigation, Data curation. **Makaiko G. Khonje:** Writing – review & editing, Validation, Investigation, Data curation. **Fredrick Mbugua:** Validation, Investigation, Data curation. **Ganeshamoorthy Rajendran:** Validation, Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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