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Postharvest handling of indigenous vegetables in Ghana: implications for reducing food loss and enhancing nutrition

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Postharvest deterioration of horticultural crops, including indigenous, traditional, neglected and underutilized vegetables continues to present significant challenges across Ghana's agricultural value chains. These crops are particularly susceptible to physiological and biochemical changes after harvest, such as moisture loss, respiration, enzymatic browning, and microbial spoilage. Inadequate postharvest handling practices and limited access to appropriate preservation technologies further exacerbate the losses due to microbial spoilage, especially among smallholder farmers and informal market actors. This study assessed the postharvest handling practices and shelf-life extension strategies employed by smallholder farmers and traders of okra, turkey berry, garden eggs, and cocoyam leaves in the Eastern, Bono East, and Ahafo regions of Ghana. A cross-sectional survey design was used, with structured interviews conducted with 270 farmers and 288 traders to document knowledge, practices, and constraints. Results revealed low overall adoption of postharvest handling technologies, although female respondents and traders demonstrated relatively higher utilization than male and farmer counterparts. Traditional preservation techniques such as sun drying were predominantly used for okra, while basic handling interventions such as cleaning, sorting, and rudimentary packaging were commonly practiced across all four crops. While drying extended shelf-life by several months, basic handling practices provided short-term quality retention, particularly for garden eggs and cocoyam leaves. Statistical analysis showed that adoption of postharvest technologies was significantly influenced by gender, education level, municipality and crop type. Key barriers identified included limited technical knowledge, inadequate infrastructure, and high implementation costs. The study highlights the need for targeted capacity-building initiatives, investment in appropriate postharvest infrastructure, and collaborative engagement with stakeholders to promote appropriate preservation technologies. Strengthening postharvest handling systems for indigenous vegetables has the potential to extend shelf life, reduce postharvest losses, enhance food availability, and contribute to improved nutrition among Ghanaian consumers.

KEYWORDS

value chain, cocoyam leaves, turkey berry, okra, garden eggs

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1 Introduction

Indigenous, neglected and underutilized vegetables are deeply rooted in the dietary habits and cultural traditions of many Ghanaian communities. These crops, such as okra (*Abelmoschus esculentus*), garden eggs (*Solanum aethiopicum*), turkey berries (*Solanum torvum*), and cocoyam leaves (*Xanthosoma sagittifolium*), are not only known to be nutritionally rich in micronutrients but are also adapted to the local environment, making them resilient to the climatic conditions (Ayim et al., 2024). They are rich sources of essential nutrients, particularly vitamins and minerals, and other non-nutritive phytochemicals (Atuna et al., 2022). Okra is a good source of vitamins A and C, calcium, and iron, while garden eggs are rich in dietary fiber and antioxidants (Sefah et al., 2024). Turkey berries are also well-recognized for their high iron content and are used to treat anemia, while cocoyam leaves are a rich source of protein and essential amino acids (Ogah, 2015; Otu et al., 2017). Despite their high nutritional, indigenous vegetables remain underrepresented in mainstream value chains, often overshadowed by more commercially dominant crops (Nyadanu and Lowor, 2015; Atuna et al., 2022). Postharvest losses of fruits and vegetables, including traditional Ghanaian vegetables pose a persistent challenge to agricultural productivity and food availability in Ghana and across sub-Saharan Africa. These crops typically have high moisture content and active postharvest metabolic processes, which accelerate physiological and biochemical changes such as respiration, wilting, senescence, enzymatic browning, and microbial spoilage (Kader, 2002; James and Zikankuba, 2017). These deteriorative processes compromise the visual, textural, and nutritional quality of fresh produce, contributing to losses estimated at 30–50% for certain perishable crops under ambient conditions (FAO, 2021; Kitinoja and Kader, 2015). The magnitude of these losses is exacerbated by poor harvesting practices, suboptimal storage conditions, lack of cold chain infrastructure, and minimal use of modern preservation technologies among smallholder farmers and informal traders.

Postharvest technologies offer critical roles to extend the shelf-life of vegetables, reduce losses and maintain the quality of horticultural produce (James and Zikankuba, 2017). In Ghana, smallholder farmers and traders predominantly rely on traditional preservative methods such as sun drying, basic sorting, cleaning and packaging (Adom et al., 1997; Asamani and Maalekuu, 2023; Elik et al., 2019; Elolu et al., 2023). While these practices can slow deterioration, they are often insufficient to prevent significant losses, particularly during the hot and humid storage period. Some traditional handling practices often contribute to physical damage in perishable vegetables, leading to quality deterioration such as wilting, microbial spoilage, and discoloration, including yellowing (Erkan and Dogan, 2019; Gogo et al., 2018). Nutrients like vitamin C and carotenoids are especially vulnerable to oxidative degradation, a process that is accelerated when mechanical damage compromises the integrity of vegetable cell walls (Velderrain-Rodríguez et al., 2019).

Storage is also critical factor required to maintain the nutrient integrity of vegetables throughout the value chain. Ideally, storage conditions for vegetables should include low temperatures, high relative humidity, and limited exposure to light. However, evidence from recent studies suggests that such optimal conditions are rarely achieved in practice, particularly for NUVs sold through local markets, due to the high cost of refrigeration and unreliable electricity supply (Gogo et al., 2018; Makule et al., 2022). Furthermore, inconsistencies in postharvest hygiene practices can further compromise product quality. For example, washing indigenous vegetables immediately after harvest has been shown to effectively reduce surface contaminants and microbial load, thereby slowing down the deterioration processes (Velderrain-Rodríguez et al., 2019, as cited in Kubitza et al., 2025). Despite the documented importance of postharvest technologies in reducing losses, limited information exists on the socio-economic factors influencing the adoption of these technologies among indigenous vegetable value chain actors in Ghana. Furthermore, the extent to which traditional and emerging postharvest strategies effectively extend shelf life and maintain quality remains poorly understood. Recent studies have called attention to the need for research-informed, low-cost postharvest innovations and capacity-building to address the knowledge and technology gaps in the indigenous vegetable subsector (Lalpekhlua et al., 2024; Asamani and Maalekuu, 2023).

This study, therefore, aimed to assess the postharvest handling practices and shelf-life extension strategies employed by smallholder farmers and traders of four selected indigenous vegetables in Ghana's Eastern, Ahafo, and Bono East regions. The selection of okra, turkey berries, garden eggs, and cocoyam leaves for this study was based on their widespread consumption, high nutritional value, and socioeconomic importance to smallholder farmers, particularly women, in the Middle Belt regions of Ghana. These crops are cultivated across diverse agroecological zones and are seasonally abundant, often resulting in gluts and elevated postharvest losses due to limited processing and storage options. The study specifically evaluated the types of postharvest interventions in use, factors influencing their adoption, and the constraints limiting their wider uptake.

1.1 Conceptual framework

This study adopts a supply chain approach to analyze the flow of indigenous vegetables in Ghana. The supply chain diagram (Figure 1) illustrates the linear flow of activities and interactions from the provision of farm inputs, to production, through to postharvest handling to transportation and trading and aggregation. The next steps are retailing and processing through to final consumption.

2 Materials and methods

2.1 Description of the study area

The study was conducted in the West Akim and Suhum municipalities in the Eastern Region; Tano North, Tano South,

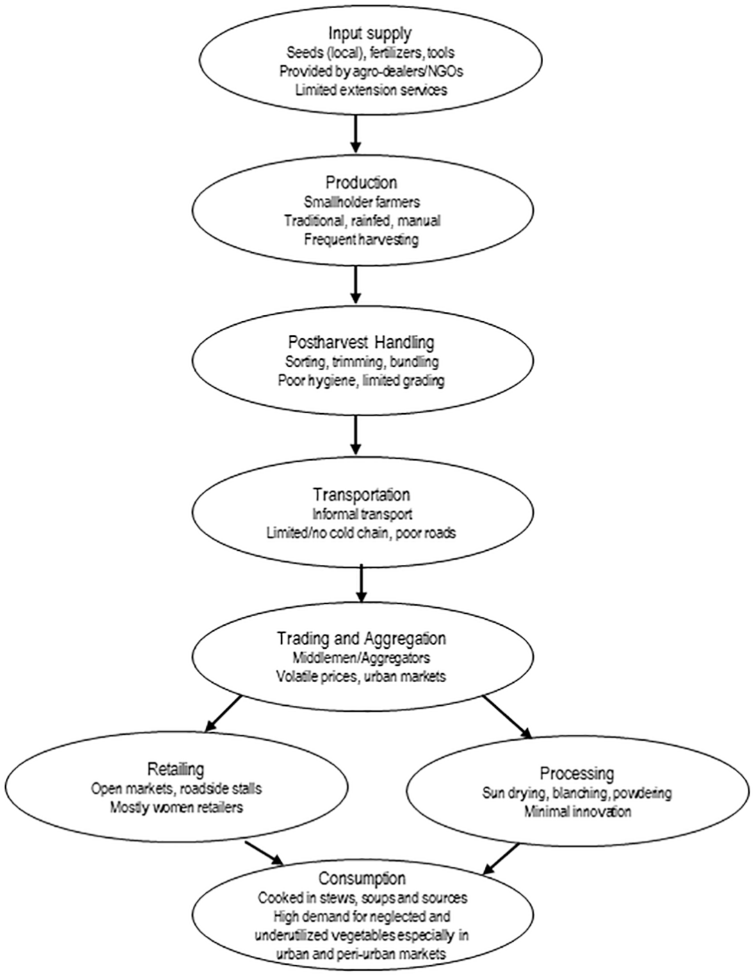

FIGURE 1
Supply chain of neglected and underutilized vegetables in Ghana.

Asunafo North, and Asunafo South Municipalities in the Ahafo Region of Ghana, as well as Techiman and Techiman North Municipalities in the Bono East Region. These regions are well recognized for producing domestic food and export commodities in significant quantities. The regions were purposively selected because of their significance in cultivating and marketing the selected Ghanaian indigenous vegetables (Ministry of Food and Agriculture, Ghana, Statistics, Research & Information Directorate, 2019; Dapaah Opoku et al., 2020).

2.2 Research design, sampling procedure, frame, and sample size

The study employed a quantitative research approach using a cross-sectional design. Primary data were collected from randomly selected farmers and traders across municipalities within the identified regions. A multistage sampling technique was adopted to ensure representation of diverse farming communities and geographical areas. In the first stage, municipalities were selected, followed by the selection of specific communities within them. Subsequently, smallholder farmers cultivating indigenous vegetables were randomly chosen. The units of analysis for the study were smallholder vegetable farmers and traders from the selected communities. The sampling frame comprised all vegetable farmers in the target regions. Inclusion criteria were limited to farmers and traders engaged in the cultivation and marketing of indigenous Ghanaian vegetables specifically okra, garden eggs, turkey berries, and cocoyam leaves (kontomire).

Cohen's effect size was employed to determine the minimum sample size required to achieve adequate statistical power for this study. A medium effect size ($w = 0.3$), as defined by Cohen, was selected based on its appropriateness for categorical data analyses involving group comparisons, specifically, chi-square tests comparing farmers and traders across different regions in terms of their use of postharvest practices. This effect size reflects the assumption that regional variations in farming and trading behaviors are likely to produce moderate, yet meaningful, differences rather than extreme contrasts. The choice of a medium effect size strikes a balance between practical significance and statistical detectability.

Incorporating Cohen's effect size into the power analysis ensured that the sample size was sufficiently robust to detect statistically meaningful differences while minimizing the likelihood of Type II errors (i.e., failing to detect an effect when one truly exists). The calculation was based on the following formula:

$$N = (\chi^2(1-\beta), df)/w^2$$

Where:

- $\chi^2(1-\beta)$, df is the critical chi-square value corresponding to the desired statistical power $(1-\beta)$ and degrees of freedom (df)
- w is the assumed effect size
- df is the degrees of freedom, calculated as (number of rows − 1)×(number of columns − 1)

This approach provided a statistically sound basis for determining the required sample size to ensure meaningful comparisons across regions. A chi-square test (goodness-of-fit or test of independence) was employed for the analysis, using a medium effect size (w = 0.3), significance level of $\alpha = 0.05$, and a statistical power of 0.80 $(1-\beta)$. With degrees of freedom (df) = 2 corresponding to comparisons across three regions, the minimum required sample size was calculated to be 88 participants.

To guide fieldwork, enumerators collaborated with the respective Directorates of Agriculture within the selected municipalities to plan sampling and data collection. Farmers and traders engaged with the selected indigenous vegetables were identified, and 10% were randomly selected from each municipality within the three target regions. To accommodate potential non-response or missing data, a 5% buffer was added to the calculated sample size. Following data cleaning, responses from 270 farmers and 288 traders were retained, providing sufficient statistical power to detect medium-sized effects in regional comparisons.

The distribution of respondents across the three regions is summarized in Table 1.

The total sample comprised 270 smallholder farmers and 288 traders.

2.3 Questionnaire development and validation

The development of the questionnaire was guided by a comprehensive review of relevant literature and previous research on postharvest handling and indigenous vegetable value chains in Ghana and other sub-Saharan African countries. The instrument was designed to capture detailed information on respondents' socio-demographic profiles, agricultural or trading activities, postharvest handling practices, encountered challenges, and the specific indigenous vegetable crops cultivated or marketed. Given the distinct roles of farmers and traders within the value chain, separate questionnaires were developed for each group to ensure relevance and contextual appropriateness. This approach allowed the study to capture group-specific insights while maintaining consistency in key thematic areas.

Prior to data collection, enumerators underwent structured training to enhance their understanding of the study's purpose, ethical considerations, and correct administration of the questionnaires. The instruments were pre-tested in the Greater Accra Region to assess question clarity, contextual relevance, and internal consistency. Based on the pre-test results, necessary revisions were made to enhance reliability.

2.4 Data collection

Interviews were conducted by trained enumerators supported by trained personnel of the regional and municipal Agricultural Extension Office of the Ministry of Food and Agriculture (MoFA), Ghana. Primary data were collected from the farmers and traders through personal interviews using semi-structured questionnaires programmed on tablets using the Kobo toolbox and translated into the local language to the best understanding of the respondents. The questionnaires were developed through an extensive literature review and consultations with key informants and experts. This was done to ensure that relevant questions eliciting the appropriate responses were addressed.

The questionnaire was pre-tested for validity and local context applicability before data collection. Pre-testing helped to refine the questionnaire and ensure clarity. The questionnaires comprised various sections categorized as demographic, production, postharvest handling, techniques, and farmers' self-reported challenges/feedback about previous production seasons. The data obtained was further cleaned to eliminate discrepancies, rectify missing data, and ensure the reliability of the data.

2.4.1 Data quality control measures

Data were reviewed on a daily basis to ensure completeness, internal consistency, and accuracy. Any missing or unclear responses were addressed through follow-up with respondents, where necessary, to validate and correct the information. To minimize entry errors and facilitate real-time data capture, the study employed KoboToolbox, an electronic data collection platform equipped with built-in validation checks and automated skip logic. All data were securely stored and backed up on a daily basis. During processing and analysis, additional quality assurance steps, including double-checks and thorough data cleaning were carried out to enhance the reliability and integrity of the dataset.

2.5 Informed consent and ethical considerations

The researchers obtained informed consent from all human participants involved in this study. Participants were reliably informed about the purpose of the study, the confidentiality and anonymity of their responses, and their rights as participants. Ethical clearance for this study was obtained from the Ethics

TABLE 1 Percentage distribution of farmers and traders in the selected regions.

Region	Farmers (%)	Traders (%)
Eastern	46	44
Ahafo	43	50
Bono	11	6
Total	100	100

Committee of the College of Basic and Applied Sciences in the University of Ghana, before the commencement of data collection.

2.6 Data analysis

Descriptive statistics in the form of percentages and cross-tabulations was utilized in this study to derive insights into the characteristics of the data collected from the farmers and traders. Chi-square analysis was conducted to examine patterns and relationships between variables and to determine the statistical significance of any observed associations. Descriptive statistics were appropriate for this study because this research aimed to present the respondents' responses to the survey items to address the aforementioned research objectives. STATA version 17 was used for the data analysis.

3 Results

3.1 Demographics of respondents

The demographic characteristics of the respondents are presented in Table 2. The summary provides an overview of the frequencies and percentage distributions of the farm sizes of the farmers, years of experience, age, gender, and level of education of the farmers and traders.

The majority of respondents were within the middle-age bracket, with 38.29% of farmers and 32.75% of traders aged between 40 and 49 years. This was followed by those aged 30 to 39, accounting for 22.30% of farmers and 25.78% of traders. Young adults aged 20 to 29 represented a smaller proportion of the sample –3.72% of farmers and 9.06% of traders, while older adults aged 60 and above constituted 9.67% of farmers and 9.06% of traders. No respondents were recorded under the age of 20 in either group. Age distribution varied across municipalities, with West Akim and Suhum recording the highest shares of traders aged 40–49 years (9.12% and 4.91% respectively), whereas Techiman North recorded the lowest proportions across most age brackets Table 3).

Suhum municipality recorded the highest proportion of farmers aged 40–49 (12.73%), whereas the youngest age group was least represented across all municipalities, with some districts such as Asunafo North and South reporting no farmers below the age of 30 (Table 4). These results underscore the dominance of older age groups in indigenous vegetable production, suggesting limited participation of youth in this sub-sector. A notable gender disparity was observed between the two groups. Males dominated the farming category, constituting 70.63%, whereas 92.36% of traders were female, highlighting the predominant role of women in the marketing of indigenous vegetables. Female dominance was consistent across all municipalities, reflecting a broader national trend in which women play a key role in informal vegetable marketing systems (Table 3). The highest representation of female farmers was observed in Tano North (9.36%), while male participation was consistently high across all municipalities, especially in Suhum and West Akim (Table 4).

In terms of educational level, the majority of both farmers and traders had primary education, accounting for 47.76% and 47.92% respectively. Secondary education was attained by 23.88% of farmers and 20.14% of traders, while a smaller proportion of respondents reported tertiary education – 3.36% of farmers and 2.43% of traders. Notably, 23.51% of farmers and 27.43% of traders had no formal education, and less than 3% in both groups had vocational training. Municipalities such as West Akim and Suhum recorded relatively higher levels of secondary education among traders, while a notable share of traders in Asunafo North and Techiman Municipal reported no formal education (Table 3).

Farming experience data revealed a workforce heavily skewed toward long-term practitioners. A majority – 62.17% of farmers – reported having more than 10 years of experience in cultivating indigenous vegetables. This long-term engagement suggests a well-established farming population with extensive familiarity with crop production and seasonal cycles. Additionally, 16.85% had 6 to 10 years of experience, while 20.97% had between 1 and 5 years. Only 0.01% of farmers reported less than one year of experience, highlighting the rarity of new entrants into indigenous vegetable farming.

Among traders, however, the experience distribution shows a more recent engagement trend. The most common experience bracket was 1 to 5 years (35.44%), followed by more than 10 years (39.30%) and 6 to 10 years (24.56%). A small proportion (0.70%) of traders reported having less than one year of experience. This pattern suggests that while a large share of traders are relatively new entrants into indigenous vegetable trading, there is also a substantial number of experienced actors in the system. Overall, the data indicate that indigenous vegetable production is primarily driven by experienced farmers, whereas the trading segment is more dynamic and inclusive of both new and seasoned participants. The predominance of experienced individuals, particularly among farmers, may positively influence postharvest practices and reduce losses through knowledge gained over time. However, the influx of less experienced traders underscores the need for targeted capacity building in postharvest handling and marketing to mitigate spoilage and shelf-life deterioration risks associated with knowledge gaps.

Farm size information, collected only from farmers, indicated that the majority (87.73%) operated on small plots ranging from 1 to 5 acres. A smaller proportion farmed between 6 and 10 acres (6.69%), and only 1.86% reported cultivating more than 10 acres. Those farming less than 1 acre represented 3.72% of the sample. Overall, the results highlight that indigenous vegetable trading in these regions is predominantly managed by women with basic

TABLE 2 Summary of demographic characteristics of respondents.

Variable	Farmers (%)	Traders (%)
Age		
<20	–	–
20–29	3.72	9.06
30–39	22.30	25.78
40–49	38.29	32.75
50–59	26.02	23.34
60 and above	9.67	9.06
Gender		
Female	29.37	92.36
Male	70.63	7.64
Level of education		
No formal education	23.51	27.43
Primary education	47.76	47.92
Secondary education	23.88	20.14
Tertiary education	3.36	2.43
Vocational training	1.49	2.09
Years of experience		
<1 year	0.01	0.70
1–5 yrs	20.97	35.44
6–10 yrs	16.85	24.56
>10 yrs	62.17	39.30
Farm size (acre)		
<1 acre	3.72	–
1–5	87.73	–
6–10	6.69	–
>10	1.86	–
Vegetables cultivated/marketed		
Okra Only	24.16	18.49
Garden Eggs Only	27.51	22.6
Turkey berry Only	1.49	5.48
Cocoyam Leaves only	4.46	9.59
Any Two	31.97	27.05
Any Three	5.58	6.16
All Four	4.83	10.62

education and considerable experience, concentrated among middle-aged adults. These characteristics suggest stability in trader engagement but also indicate opportunities for capacity building, especially in literacy and business management skills, to enhance market performance and postharvest practices.

Respondents reported various levels of crop specialization. Among farmers, 24.16% cultivated only okra, 27.51% focused solely on garden eggs, and a smaller proportion produced only cocoyam leaves (4.46%) or turkey berries (1.49%). Traders showed a slightly different pattern, with 22.6% marketing only garden eggs, 18.49% selling only okra, and higher proportions handling cocoyam leaves (9.59%) and turkey berries (5.48%) compared to farmers. Garden eggs were the most common single crop cultivated and marketed by farmers and traders in the selected regions. A significant number of both farmers (31.97%) and traders (27.05%) were engaged in the cultivation or marketing of any two vegetables. Moreover, 5.58% of farmers and 6.16% of traders handled any three, while 4.83% of farmers and 10.62% of traders dealt with all four indigenous vegetables. These findings suggest a tendency toward crop diversification among traders, possibly in response to market demand.

3.2 Factors influencing the utilization of postharvest techniques among farmers and traders

Table 5 presents the Chi-square distribution of factors influencing the utilization of Postharvest technologies for selected indigenous vegetables among farmers and traders in the study municipalities. The analysis examines the associations between postharvest technology use and socio-demographic variables including gender, age, level of education, years of experience, and municipality. These factors were evaluated in relation to the four key crops studied – okra, garden eggs, turkey berries, and cocoyam leaves. The results highlight the degree to which each variable significantly contributes to the adoption of postharvest handling practices across different value chain actors and crop types.

Chi-square (χ^2) analysis was conducted to examine the relationship between socio-demographic variables (gender, years of experience, age, municipality, and education level) and the utilization of postharvest technologies across four indigenous vegetables – okra, garden eggs, turkey berries, and cocoyam leaves among farmers and traders (Table 5). The analysis identifies key socio-economic and geographic determinants that influence postharvest practices.

Among farmers, the results showed that gender, years of experience, age, education level, and especially municipality had significant associations with postharvest technology utilization for specific crops. For okra, statistically significant associations were observed for gender ($\chi^2 = 22.64$, $p = 0.00$), experience ($\chi^2 = 31.59$, $p = 0.00$), and age ($\chi^2 = 46.19$, $p = 0.00$), indicating that male farmers with more years of farming, and older age groups were more likely to adopt postharvest technologies. A strong regional influence was evident, with municipality showing a significant relationship across all crops – okra ($\chi^2 = 315.26$, $p = 0.00$), garden eggs ($\chi^2 = 268.80$, $p = 0.00$), turkey berries ($\chi^2 = 42.03$, $p = 0.01$), and cocoyam leaves ($\chi^2 = 41.63$, $p = 0.00$). This underscores the geographical disparity in access and adoption of postharvest innovations.

TABLE 3 Demographic distribution of traders in the selected municipalities.

Variable	Eastern Region		Ahafo Region				Bono East Region		Total
	West Akim	Suhum	Asunafo North	Asunafo South	Tano North	Tano South	Techiman Municipal	Techiman North	
	Percentage (%)								
Age									
20–29	1.40	1.05	0.70	2.46	1.05	0.35	1.75	0.00	8.77
30–39	7.02	2.81	2.11	4.56	2.81	2.11	4.21	0.35	25.96
40–49	9.12	4.91	2.81	3.86	4.21	3.86	2.46	1.40	32.63
50–59	7.02	6.67	2.11	2.11	0.70	2.11	1.75	1.05	23.51
> 60	2.11	1.75	1.05	0.70	3.51	0.00	0.00	0.00	9.12
Total	26.67	17.19	8.77	13.68	12.28	8.42	10.18	2.81	100.00
Gender									
Female	26.92	16.43	8.39	11.19	9.09	8.39	9.09	2.80	92.31
Male	0.00	0.70	0.35	2.45	3.15	0.00	1.05	0.00	7.69
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Education									
None	5.94	5.24	4.20	3.15	2.80	2.80	3.15	0.70	27.97
Basic	12.24	10.14	3.85	4.90	7.69	4.55	2.80	1.75	47.90
Secondary	5.94	1.75	0.70	4.90	1.05	1.05	4.20	0.35	19.93
Vocational	2.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10
Tertiary	0.70	0.00	0.00	0.70	0.70	0.00	0.00	0.00	2.10
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Experience									
<1 year	0.00	0.00	0.00	0.35	0.00	0.00	0.35	0.00	0.70
1–5 yrs	4.56	3.16	3.86	6.31	8.07	2.11	5.61	1.75	35.44
6–10 yrs	5.96	4.56	3.16	4.21	3.16	0.70	2.46	0.35	24.56
>10 yrs	16.14	9.47	1.75	2.81	1.05	5.61	1.75	0.70	39.30
	26.67	17.19	8.77	13.68	12.28	8.42	10.18	2.81	100.00
Crop									
Okra	12.94	8.04	3.85	6.29	2.80	8.39	8.74	1.75	52.80
Garden eggs	14.69	8.74	3.15	5.94	7.34	8.39	6.99	2.10	57.34
Turkey berry	10.84	5.24	1.05	2.10	0.70	6.99	1.05	0.00	27.97
Cocoyam leaves	11.89	5.94	0.70	3.50	1.40	5.59	1.05	0.35	30.42

In the case of garden eggs, all variables except education level (p = 0.70) were significantly associated with postharvest technology utilization among farmers, with particularly strong associations for experience (χ^2 = 37.80, p = 0.00) and municipality. This suggests that more experienced farmers and those in specific regions are more likely to engage in postharvest handling practices such as sorting, bundling, or drying. For turkey berries, municipality was the only significant variable (χ^2 = 42.03, p = 0.01), while no significant associations were found for gender, experience, age, or education. A similar pattern was observed for cocoyam leaves, where age (χ^2 = 16.83, p = 0.01) and municipality (χ^2 = 41.63, p = 0.00) were significantly associated with postharvest technology use. These results point to product-specific dynamics in technology adoption, with regional context playing a decisive role. Among

TABLE 4 Demographic distribution of farmers in the selected municipalities.

Variable	Eastern Region		Ahafo Region				Bono East Region		Total
	West Akim	Suhum	Asunafo North	Asunafo South	Tano North	Tano South	Techiman Municipal	Techiman North	
	Percentage (%)								
Age									
20–29	0.37	0.75	0.00	0.00	1.12	0.00	0.75	0.75	3.75
30–39	4.87	5.24	1.12	3.37	2.62	2.25	0.37	2.62	22.47
40–49	6.37	12.73	3.00	3.37	3.37	2.62	4.12	3.00	38.58
50–59	7.87	4.49	1.87	0.75	2.62	3.37	2.25	1.87	25.09
> 60	1.87	1.50	1.50	0.00	3.37	0.75	0.00	1.12	10.11
Total	21.35	24.72	7.49	7.49	13.11	8.99	7.49	9.36	100.00
Gender									
Female	1.50	4.12	2.62	1.12	9.36	3.37	3.75	3.37	29.21
Male	19.85	20.60	4.87	6.37	3.75	5.62	3.75	5.99	70.79
Total	21.35	24.72	7.49	7.49	13.11	8.99	7.49	9.36	100.00
Education									
None	4.12	8.24	3.75	5.62	5.24	3.37	5.24	4.87	40.45
Basic	17.23	16.48	3.75	1.87	7.87	5.62	2.25	4.49	59.55
Total	21.35	24.72	7.49	7.49	13.11	8.99	7.49	9.36	100.00
Experience									
1–5 yrs	2.62	1.50	2.62	1.50	5.62	0.37	3.75	3.00	20.97
6–10 yrs	1.87	2.25	1.50	3.00	1.50	0.75	2.62	3.37	16.85
>10 yrs	16.85	20.97	3.37	3.00	5.99	7.87	1.12	3.00	62.17
Total	21.35	24.72	7.49	7.49	13.11	8.99	7.49	9.36	100.00
Farm Size									
<1 acre	0.00	0.00	0.00	1.15	0.00	1.15	1.53	0.00	3.82
1–5	19.47	22.52	6.87	6.49	12.60	6.87	6.11	7.63	88.55
6–10	2.29	1.53	0.38	0.00	0.76	0.38	0.00	1.15	6.49
>10	0.00	1.15	0.00	0.00	0.00	0.00	0.00	0.00	1.15
Total	21.76	25.19	7.25	7.63	13.36	8.40	7.63	8.78	100.00
Crop									
Okra	12.73	20.60	3.37	5.24	3.37	7.87	5.99	5.24	64.42
Garden eggs	20.22	16.10	2.25	4.12	7.87	6.74	5.24	4.87	67.42
Turkey berry	1.50	5.62	0.37	0.00	0.37	1.50	1.12	0.75	11.24
Cocoyam leaves	1.87	4.12	1.87	0.37	1.50	1.87	1.50	1.50	14.61

traders, fewer statistically significant associations were observed. For garden eggs, gender ($\chi^2 = 17.94$, $p = 0.01$) and municipality ($\chi^2 = 276.04$, $p = 0.00$) were the only influential factors. For cocoyam leaves, municipality ($\chi^2 = 175.23$, $p = 0.00$) and education level ($\chi^2 = 49.57$, $p = 0.01$) were significantly associated with postharvest practices. This highlights the importance of location and literacy in shaping postharvest decision-making among market actors.

TABLE 5 Chi 2 square distribution of factors influencing the utilization of postharvest technologies for the selected crops among farmers and traders in the selected municipalities.

Chi 2/Probability										
Variables	Gender		Years of experience		Age		Municipality		Education Level	
Crop	Farmer	Trader	Farmer	Trader	Farmer	Trader	Farmer	Traders	Farmer	Traders
Okra	22.64 P=0.00*	12.63 P=0.08	31.59 P=0.00*	29.90 P=0.37	46.19 P=0.00*	39.48 P=0.07	315.26 P=0.00*	242.94 P=0.00*	12.23 P=0.06	16.23 P=0.88
Garden eggs	18.39 P=0.00*	17.94 P= 0.01*	37.8 P=0.00*	24.90 P=0.41	17.04 P=0.65	27.65 P=0.28	268.80 P=0.00*	276.04 P=0.00*	3.01 P (0.70)	86.23 P=0.43
Turkey Berry	5.82 P=0.21	6.14 P= 0.29	4.64 P=0.80	29.36 P=0.08	18.12 P=0.32	5.96 P=0.17	42.03 P=0.01	251.46 P=0.00	0.90 P=0.93	17.90 P=0.93
Cocoyam Leaves	1.03 P=0.60	6.81 P=0.45	2.4221 P=0.66	25.96 P=0.58	16.8256 P=0.01*	22.09 P=0.78	41.63 P=0.00	175.23 P=0.00*	1.03 P 0.60	49.57 P=0.01*

p-values followed by * are significantly different.

Overall, municipality consistently emerged as the most influential factor affecting the distribution and use of postharvest technologies across all crops and respondent categories. This reflects uneven development in infrastructure, knowledge dissemination, and market access across regions. Among farmers, gender, experience, and age were also important drivers of technology utilization, particularly for okra and garden eggs. Among traders, demographic factors were less influential, with location and education playing a more prominent role. These findings emphasize the need for targeted postharvest interventions that consider crop-specific needs, local infrastructure disparities, and demographic characteristics to enhance the uptake and impact of postharvest technologies along the indigenous vegetable value chain in Ghana.

3.3 Comparison of postharvest handling methods used by farmers and traders across the selected municipalities

A comparative analysis of postharvest handling methods adopted by farmers and traders of indigenous vegetables across eight municipalities in three regions revealed significant similarities in practice, as well as gaps in the adoption of preservation-enhancing technologies (Tables 6 and 7).

For all four crops – okra, garden eggs, turkey berry, and cocoyam leaves – the predominant method reported by both farmers and traders was no postharvest handling. This indicates severe constraints in access to preservation infrastructure and knowledge. This was most pronounced for turkey berry and cocoyam leaves, with 79.37% and 77.62% of farmers respectively, and similar proportions of traders, also indicating no postharvest practices. Sorting and grading emerged as the most commonly adopted technique among those who implemented any handling measures. Farmers of garden eggs (23.43%) and okra (15.38%) reported moderate use of sorting, with traders mirroring these trends, albeit at lower levels. Use of packaging, mainly involving sacks or baskets, was also more prevalent among okra (10.49%) and garden egg (6.29%) farmers and traders, particularly in Techiman Municipal and Tano South.

Notably, cold storage and drying were among the least adopted methods by both groups. Cold storage usage remained below 3% across all commodities and actors, while drying was largely limited to cocoyam leaves and turkey berries, primarily among farmers in Tano South. Traders almost entirely lacked access to these technologies. The use of combined methods (e.g., any two or three practices) was limited, with only 7.34% of okra farmers and 2.45% of garden egg farmers employing more than one method concurrently. A similarly low rate was recorded among traders.

While these technologies are generally affordable and scalable, adoption may be hindered by limited access to finance, lack of awareness, and inadequate training. Therefore, targeted subsidies and market incentives can enhance adoption and improve the economic resilience of actors across the indigenous vegetable value chain.

The findings also indicate a strong need for targeted interventions to enhance postharvest handling capacity among both farmers and traders. This includes the introduction of low-cost cold chain solutions, training in sorting and hygienic packaging, and the promotion of drying and room storage for shelf-life extension, especially critical given the perishability of these indigenous vegetables.

3.4 Challenges hampering the utilization of postharvest techniques and technologies among farmers and traders engaging with indigenous Ghanaian vegetables in the middle belt of Ghana

The study identified a range of challenges that constrain the effective utilization of postharvest techniques and technologies by both farmers and traders of indigenous vegetables in the Eastern, Bono East, and Ahafo regions of Ghana (Figures 2, 3).

Among farmers, the most frequently cited challenge was the lack of knowledge and technical skills, reported by over 60% of respondents. This highlights the widespread deficiency in extension services and training programs that could otherwise enhance awareness and adoption of best practices. Closely following was

TABLE 6 Postharvest handling methods employed by farmers in the selected municipalities.

Crop	Eastern Region		Ahafo Region				Bono East Region		Total
	West Akim	Suhum	Asunafo North	Asunafo South	Tano North	Tano South	Techiman Municipal	Techiman North	
	Percentage (%)								
Okra									
None	15.73	9.09	8.74	9.44	10.84	0.35	4.20	1.40	59.79
Sorting and grading	8.04	5.24	0.00	0.70	0.00	0.00	0.35	1.05	15.38
Cold storage	0.00	0.00	0.00	0.70	0.70	0.35	0.00	0.35	2.10
Packaging	0.35	0.00	0.00	2.10	0.00	4.90	3.15	0.00	10.49
Drying	0.00	0.35	0.00	0.00	0.00	1.75	0.00	0.00	2.10
Any two	2.45	2.10	0.00	0.35	0.00	0.00	2.45	0.00	7.34
Any three	0.00	0.35	0.00	0.00	0.00	0.35	0.00	0.00	0.70
Room storage	0.35	0.00	0.00	0.35	0.70	0.70	0.00	0.00	2.10
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Garden eggs									
None	15.03	8.39	8.39	10.49	8.39	1.05	4.20	2.10	58.04
Sorting and grading	10.84	8.39	0.00	1.05	0.00	0.35	2.45	0.35	23.43
Cold storage	0.00	0.00	0.35	0.70	1.05	0.00	0.00	0.00	2.10
Packaging	0.70	0.00	0.00	0.35	0.00	4.90	0.00	0.35	6.29
Any two	0.00	0.35	0.00	0.00	0.00	0.00	2.10	0.00	2.45
Any three	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
Room storage	0.00	0.00	0.00	1.05	2.80	2.10	1.40	0.00	7.34
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Turkey berry									
None	18.53	14.34	8.74	13.29	11.54	0.70	9.44	2.80	79.37
Sorting and grading	4.90	2.45	0.00	0.00	0.00	0.00	0.35	0.00	7.69
Packaging	0.35	0.00	0.00	0.35	0.00	5.59	0.35	0.00	6.64
Drying	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35
Any two	2.80	0.35	0.00	0.00	0.00	0.00	0.00	0.00	3.15
Room storage	0.35	0.00	0.00	0.00	0.70	1.75	0.00	0.00	2.80
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Cocoyam leaves									
None	16.78	12.24	8.74	12.59	11.54	3.85	9.44	2.45	77.62
Sorting and grading	8.39	4.20	0.00	0.00	0.00	0.00	0.00	0.00	12.59
Cold storage	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.70
Packaging	0.70	0.35	0.00	0.00	0.00	3.15	0.00	0.00	4.20
Spraying with water	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.70

(Continued)

TABLE 6 Continued

Crop	Eastern Region		Ahafo Region				Bono East Region		Total
	West Akim	Suhum	Asunafo North	Asunafo South	Tano North	Tano South	Techiman Municipal	Techiman North	
	Percentage (%)								
Cocoyam leaves									
Drying	0.35	0.00	0.00	0.70	0.00	0.00	0.35	0.00	1.40
Any two	0.35	0.35	0.00	0.00	0.00	0.35	0.35	0.35	1.75
Room storage	0.35	0.00	0.00	0.00	0.35	0.35	0.00	0.00	1.05
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00

the unavailability of appropriate technologies, particularly in rural farming communities where access to cold storage, improved packaging, and processing equipment is minimal. High cost of postharvest technologies was also noted by more than half of the respondents, which indicates that affordability remains a major barrier, especially for smallholder farmers operating on limited capital. Additionally, poor market access and low returns on investment were identified as demotivating factors, discouraging farmers from investing in postharvest improvements. A smaller but notable proportion also reported poor infrastructure, such as lack of storage facilities and inadequate roads, which indirectly affect the willingness and ability to adopt technologies that require efficient logistics.

Among traders, the pattern of challenges was similar, though nuanced by their roles in the supply chain. High costs of postharvest equipment and materials emerged as the most dominant constraint. Limited space for storage and lack of cooling infrastructure in market centers were also major concerns, which reflects the urban-based yet informal nature of trading operations. A significant number of traders also cited limited awareness and technical capacity, pointing to a gap in knowledge transfer between producers and market actors. Perceived lack of government support and limited credit access were mentioned by both farmers and traders as systemic constraints. These institutional and financial barriers reduce the incentives for actors across the value chain to invest in improved postharvest systems.

Overall, these findings underscore the multifaceted nature of constraints to postharvest technology adoption, with implications for high rates of postharvest deterioration resulting in losses across the indigenous vegetable value chain. Addressing these barriers through coordinated policy support, training, and infrastructure development will be critical to improve the shelf life, safety, and profitability of indigenous vegetables in Ghana.

4 Discussion

4.1 Demographics of respondents

The demographic profile of respondents in this study reveals several critical factors that influence the utilization of postharvest technologies and the risk of postharvest deterioration and losses in indigenous vegetables. Age, gender, education, experience, and crop specialization were all shown to affect how farmers and traders engage in postharvest handling, thus impacting the overall integrity and marketability of perishable produce.

A dominant proportion of respondents were within the middle-age brackets (30–49 years), with 38.29% of farmers and 32.75% of traders aged 40–49, and over 22% of both groups in the 30–39 age range. These findings align with prior research that has shown agricultural labor in Ghana and many parts of Sub-Saharan Africa is predominantly undertaken by older adults, with younger populations showing limited interest in farming (Amankwah et al., 2021). This demographic skew toward older farmers may hinder innovation uptake, particularly the use of new postharvest handling techniques and equipment (Kabi et al., 2020). Younger individuals, who may be more open to experimenting with or adopting technologies such as solar dryers, improved packaging, or cold storage, are underrepresented. Their absence could reduce the overall resilience of the supply chain to postharvest deterioration, which is especially critical for high-moisture, fast-spoiling indigenous vegetables like cocoyam leaves and garden eggs (Kitinoja and AlHassan, 2012).

While men dominated farming (70.63%), women were overwhelmingly represented among traders (92.36%), corroborating other studies highlighting women's central role in informal fresh produce markets in Ghana and West Africa (FAO, 2011; Acquah and Onumah, 2014). However, women's limited access to training, storage infrastructure, and financial services has been cited as a key barrier to improved postharvest management (Affognon et al., 2015). This is particularly problematic since women manage much of the downstream handling of vegetables from transport to market storage and to retailing where the risk of spoilage is highest. Thus, the gendered structure of the indigenous vegetable value chain demands gender-responsive interventions that empower female traders with both knowledge and tools to reduce losses.

Education levels further influenced respondents' behavior to postharvest management. Nearly half of both farmers and traders had only basic education, while about a quarter had no formal education. Limited literacy can pose challenges for understanding proper handling protocols, how to access extension services, or in the adoption of written postharvest guidelines (Osei-Akoto et al.,

TABLE 7 Postharvest handling methods employed by traders in the selected municipalities.

Crop	Eastern Region		Ahafo Region				Bono East Region		Total
	West Akim	Suhum	Asunafo North	Asunafo South	Tano North	Tano South	Techiman Municipal	Techiman North	
	Percentage (%)								
Okra									
None	15.73	9.09	8.74	9.44	10.84	0.35	4.20	1.40	59.79
Sorting & grading	8.04	5.24	0.00	0.70	0.00	0.00	0.35	1.05	15.38
Cold storage	0.00	0.00	0.00	0.70	0.70	0.35	0.00	0.35	2.10
Packaging	0.35	0.00	0.00	2.10	0.00	4.90	3.15	0.00	10.49
Drying	0.00	0.35	0.00	0.00	0.00	1.75	0.00	0.00	2.10
Any two	2.45	2.10	0.00	0.35	0.00	0.00	2.45	0.00	7.34
Any three	0.00	0.35	0.00	0.00	0.00	0.35	0.00	0.00	0.70
Room storage	0.35	0.00	0.00	0.35	0.70	0.70	0.00	0.00	2.10
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Garden eggs									
None	15.03	8.39	8.39	10.49	8.39	1.05	4.20	2.10	58.04
Sorting and grading	10.84	8.39	0.00	1.05	0.00	0.35	2.45	0.35	23.43
Cold storage	0.00	0.00	0.35	0.70	1.05	0.00	0.00	0.00	2.10
Packaging	0.70	0.00	0.00	0.35	0.00	4.90	0.00	0.35	6.29
Any two	0.00	0.35	0.00	0.00	0.00	0.00	2.10	0.00	2.45
Any three	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
Room storage	0.00	0.00	0.00	1.05	2.80	2.10	1.40	0.00	7.34
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
Turkey berry									
None	18.53	14.34	8.74	13.29	11.54	0.70	9.44	2.80	79.37
Sorting and grading	4.90	2.45	0.00	0.00	0.00	0.00	0.35	0.00	7.69
Packaging	0.35	0.00	0.00	0.35	0.00	5.59	0.35	0.00	6.64
Drying	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.35
Any two	2.80	0.35	0.00	0.00	0.00	0.00	0.00	0.00	3.15
Room storage	0.35	0.00	0.00	0.00	0.70	1.75	0.00	0.00	2.80
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00
None	16.78	12.24	8.74	12.59	11.54	3.85	9.44	2.45	77.62
Sorting and grading	8.39	4.20	0.00	0.00	0.00	0.00	0.00	0.00	12.59
Cold storage	0.00	0.00	0.00	0.35	0.35	0.00	0.00	0.00	0.70
Packaging	0.70	0.35	0.00	0.00	0.00	3.15	0.00	0.00	4.20
Spraying with water	0.00	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.70
Drying	0.35	0.00	0.00	0.70	0.00	0.00	0.35	0.00	1.40

(Continued)

TABLE 7 Continued

Crop	Eastern Region		Ahafo Region				Bono East Region		Total
	West Akim	Suhum	Asunafo North	Asunafo South	Tano North	Tano South	Techiman Municipal	Techiman North	
	Percentage (%)								
Turkey berry									
Any two	0.35	0.35	0.00	0.00	0.00	0.35	0.35	0.35	1.75
Room storage	0.35	0.00	0.00	0.00	0.35	0.35	0.00	0.00	1.05
Total	26.92	17.13	8.74	13.64	12.24	8.39	10.14	2.80	100.00

2020). In contrast, previous studies have associated higher education levels with increased likelihood to adopt technologies that reduce spoilage, such as improved crates or on-farm storage solutions (Mitchikpe et al., 2008). The low educational level observed among the respondents, particularly traders in areas like Asunafo North and Techiman, may contribute to the persistence of poor postharvest practices such as the use of sacks for transport, improper drying, or minimal grading and sorting, all of which accelerate product deterioration.

The experience profile of indigenous vegetable farmers and traders in Ghana's middle belt reveals important implications for postharvest management and the reduction of losses. The data showed that a large majority of farmers (62.17%) had been in vegetable production for over a decade, which indicates a mature farming population with considerable institutional knowledge. This aligns with previous research suggesting that experience enhances farmers' ability to implement effective postharvest handling practices through accumulated knowledge of crop behavior, spoilage risks, and appropriate interventions (Mkamilo and Hella, 2012; Kitinoja et al., 2011).

In contrast, traders showed a more balanced distribution across experience levels, with the highest proportion (35.44%) falling within the 1–5 year range. This influx of relatively newer entrants into the trading space suggests a dynamic and evolving marketing segment, possibly driven by expanding market opportunities or increased demand for indigenous vegetables (Abdoulaye et al., 2015). However, the presence of a sizeable proportion (39.30%) with over 10 years of experience also reflects the retention of institutional knowledge within the trading sector. Experience can be closely linked to adoption of postharvest innovations. Long-standing farmers are more likely to have adopted practices such as timely harvesting, field-level sorting, and sun drying, which can significantly reduce physiological and microbial deterioration in perishable crops like okra and garden eggs (FAO, 2017). These practices help mitigate rapid postharvest degradation in indigenous vegetables due to their high moisture content and inadequate handling infrastructure. Conversely, the presence of less experienced traders may translate into inconsistent postharvest practices, contributing to losses, especially in crops like cocoyam leaves and turkey berries which are highly perishable and less well-known in terms of optimal storage conditions (Osei-Asare et al., 2011). The disparity in experience levels between farmers and traders also signals a need for tailored interventions. While experienced farmers may benefit from more advanced postharvest technologies (e.g., evaporative cooling, modified packaging), newer traders may require foundational training in basic hygiene, grading, and transportation practices. This is particularly critical given the central role traders play in aggregating, transporting, and retailing indigenous vegetables which are the processes during which most losses typically occur (Kitinoja and AlHassan, 2012).

Farm size, reported only for farmers, showed a heavy concentration (87.73%) on small plots between 1–5 acres. Smallholder farmers typically lack access to infrastructure like packhouses, cold storage, or drying sheds, which are necessary to prevent quality degradation (FAO, 2013). Their scale limits economies of scale that justify investments in postharvest technologies, making communal infrastructure and cooperative models critical for sustainability. Both farmers and traders in the study areas commonly engaged with at least two indigenous vegetable crops, which reflects a diversification strategy widely observed among smallholder systems (Heltberg and Tarp, 2002; Kassie et al., 2015). Such diversification serves as a risk management approach, that enables actors to mitigate production and market uncertainties which arise from price fluctuations and climate variability. The relatively higher proportion of traders involved in the postharvest handling of all four crops supports existing literature on market-oriented behavior, where traders often aggregate a diverse range of commodities to meet varying consumer preferences and to capitalize on market opportunities (Reardon et al., 2003). This multi-crop engagement also facilitates continuous market presence across staggered harvest periods. In contrast, farmers' tendencies toward crop specialization may be attributed to a focus on crops with established market demand or those best suited to local agro-ecological conditions, as suggested by Osei-Asare et al. (2011).

Traders exhibited slightly higher levels of specialization in specific crops such as cocoyam leaves and turkey berries, which possibly reflects niche demand in particular urban markets where these vegetables are more highly valued. These patterns are in line with previous findings from Ghana and the broader West African region, which indicate that while farmers tend to diversify modestly for livelihood stability, traders often pursue broader diversification to enhance profitability and ensure consistent supply (Abdoulaye et al., 2015; FAO, 2017).

In summary, the demographic characteristics of farmers and traders significantly shape the extent and nature of postharvest losses in indigenous vegetables. The dominance of older age groups, limited formal education, and gendered roles in marketing systems all influence how produce is handled, stored, and sold. Without context-specific interventions that address these socio-demographic barriers, efforts to extend shelf life and reduce postharvest loss may fall short.

4.2 Factors influencing the utilization of postharvest techniques among farmers and traders

This study provides critical insights into the socio-demographic and contextual factors that shape the utilization of postharvest technologies among farmers and traders of indigenous vegetables in Ghana. The findings highlight how variables such as location, gender, experience, and education influence the adoption of practices that directly impact postharvest deterioration, shelf-life extension, and the scale of postharvest losses.

A particularly strong and consistent association was found between municipality and the utilization of postharvest technologies across all vegetable types. This underscores the geographic disparities in infrastructural development, access to markets, and extension support as factors that have been previously identified as key determinants of postharvest performance in Sub-Saharan Africa (Affognon et al., 2015; FAO, 2011). Municipalities with stronger institutional presence and better-developed market systems were more likely to exhibit higher levels of adoption of essential postharvest practices such as sorting, sun-drying, bundling, and the use of basic packaging materials. These practices are critical to slow down physiological deterioration and microbial spoilage, particularly in highly perishable vegetables like okra, garden eggs, turkey berries, and cocoyam leaves (Kitinoja and AlHassan, 2012; Kader, 2005).

The results further suggest that shelf-life deterioration in indigenous vegetables, primarily driven by high moisture content, high respiration rates, and poor hygiene, can be substantially reduced through targeted postharvest interventions. Among farmers, demographic factors such as gender, age, and years of farming experience showed significant associations with the use of postharvest techniques, particularly for okra and garden eggs. Older and more experienced farmers, as well as male farmers, were more likely to adopt improved handling practices. This could be attributed to their accumulated practical knowledge, enhanced access to resources, and stronger connections to markets, which often drive demand for quality maintenance (Osei-Akoto et al., 2020; Bua et al., 2020). Even simple interventions such as harvesting under shade, prompt field sorting, or sun drying can play a vital role in delaying senescence and reducing microbial contamination, thereby extending shelf life and minimizing losses.

Among traders, municipality and education level had more significant effects than gender or experience. This reflects the critical role of awareness and knowledge access in determining technology use in informal market systems. Traders who operate in better-connected municipalities or who have some formal education are more likely to understand and apply basic postharvest techniques. Conversely, traders in informal or poorly resourced markets face multiple constraints such as, inadequate storage space, lack of cooling infrastructure, and limited sanitation, which accelerate the deterioration of perishable vegetables like turkey berries and cocoyam leaves (Ndiaye et al., 2021; MoFA, 2020).

Despite their considerable nutritional and cultural value, indigenous vegetables remain underutilized largely due to their perishability and the postharvest handling gaps identified in this study. These gaps restrict the marketability and availability of the produce, resulting in high volumes of waste, income loss, and reduced dietary diversity. Prior research has shown that postharvest losses for perishable crops in Ghana can range from 30% to 50% (FAO, 2013; Affognon et al., 2015), figures that reflect both technical limitations and systemic neglect.

The low adoption of postharvest practices for less-promoted crops such as turkey berries and cocoyam leaves is especially concerning. These crops have high respiration rates and are often transported and sold under minimal protection, exacerbating their susceptibility to wilting, browning, and decay (Kader, 2005; Kitinoja and AlHassan, 2012). Addressing this issue requires more attention in postharvest policy and programming to ensure inclusive strategies that do not overlook crops of high local importance. Therefore, a multidimensional response is essential. Low-cost, context-appropriate technologies, such as improved crates, evaporative coolers, and solar dryers, must be promoted alongside capacity building that is sensitive to the needs of women, less-educated actors, and those in underserved areas. Extension programs should integrate postharvest training modules and prioritize outreach to younger and less-experienced farmers and traders.

4.3 Comparison of postharvest handling methods and challenges hampering the utilization of postharvest techniques among farmers and traders in the selected municipalities

4.3.1 Comparison of postharvest handling methods

The results of this study highlight a widespread underutilization of effective postharvest handling methods among farmers and traders of indigenous vegetables in Ghana, with critical implications for postharvest deterioration and loss. The high perishability of crops such as those okra used in this study makes them especially vulnerable to rapid quality decline when not properly handled (Osei-Akoto et al., 2020; Affognon et al., 2015). A significant proportion of respondents across municipalities reported no use of formal postharvest practices with figures

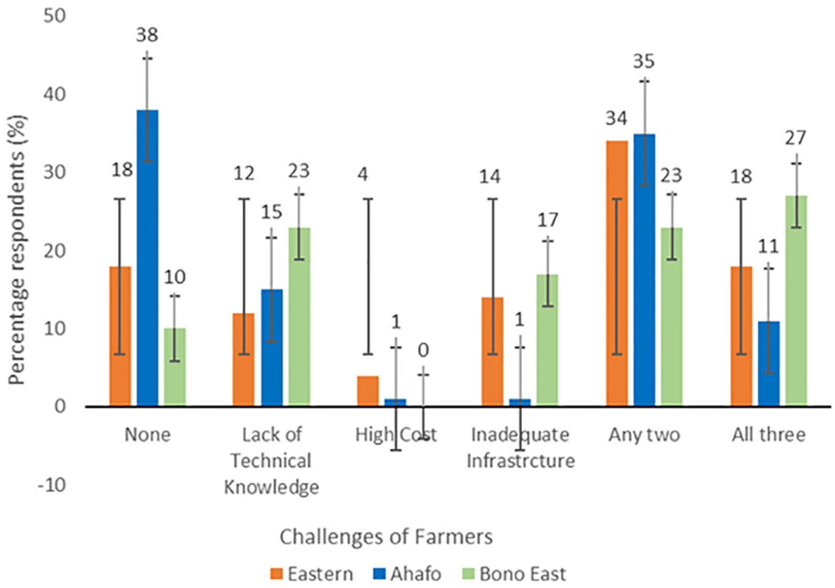

FIGURE 2
Challenges hampering the utilization of postharvest techniques and technologies among famers in the Eastern, Bono East, and Ahafo Regions of Ghana.

ranging from over 60% for okra and turkey berries, and more than 70% for cocoyam leaves. This absence of basic interventions such as cleaning, grading, packaging, and temperature control facilitates rapid physiological degradation and microbial spoilage, contributing to substantial quality and nutritional losses (Kader, 2005; Kitinoja and AlHassan, 2012). Low utilization rates may also be linked to other factors, such as arrangements between farmers and aggregators or traders who purchase produce directly from the farm gate. The drying technology used by okra farmers may be partly explained by the need to preserve seeds for subsequent planting seasons. On the other hand, according to Affognon et al. (2015), postharvest losses in sub-Saharan Africa are significantly influenced by inadequate storage and processing technologies, making drying a crucial alternative for extending shelf life and

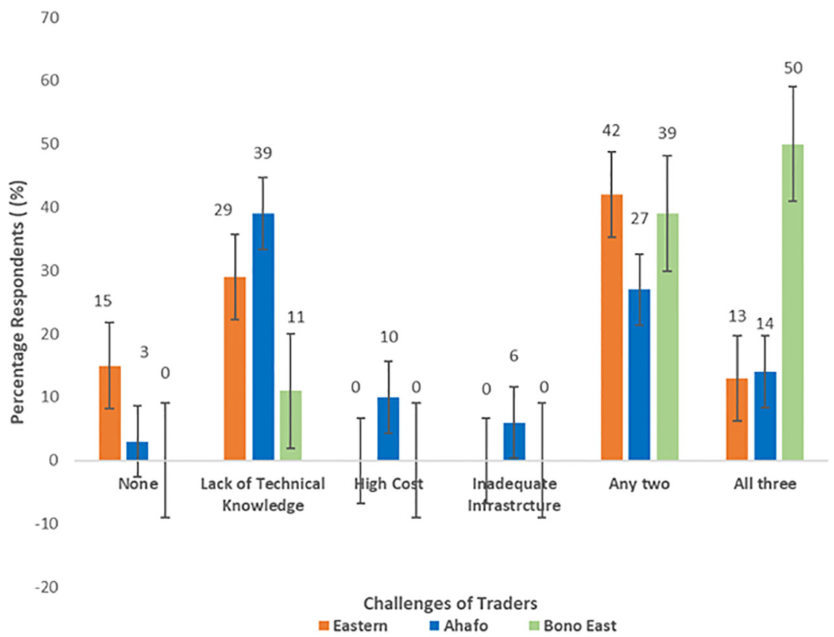

FIGURE 3
Challenges hampering the utilization of postharvest techniques and technologies among traders in the Eastern, Bono East, and Ahafo Regions of Ghana.

reducing waste. Studies by Mujibha et al. (2021) also indicate that although its efficiency is often limited by environmental conditions, traditional sun drying is the most accessible and affordable method among smallholder farmers.

Significant variations across municipalities reinforce previous findings that local context, including infrastructure, extension services, and market facilities, critically shapes technology adoption (Kansanga et al., 2025; Osei-Kwarteng et al., 2017). The relatively higher use of sorting and grading in West Akim and packaging in Tano South might indicate localized initiatives or better market linkage that encourage these practices. Although sorting and grading were the most commonly reported practices, their limited application and inconsistent implementation significantly reduces their potential impact. These practices alone cannot sufficiently prevent mechanical injuries, microbial contamination, and water loss, especially in the absence of protective packaging and cold storage (FAO, 2013). The extremely low adoption of cold storage, which is a critical technology necessary to maintain freshness and extend shelf life, reflects broader infrastructural and financial barriers faced by smallholder farmers and informal market actors (Ndiaye et al., 2021).

Overall, the non-utilization of postharvest handling techniques among farmers and traders highlights significant risks to maintaining the quality of fresh vegetables. While experience in farming or marketing the selected vegetables may drive adoption for more commercially dynamic crops like okra and garden eggs, it may not be particularly relevant for crops that are either more traditional or niche. Similar mixed effects of experience have been observed by Kiburi et al. (2020). The significant association between education level and the utilization of postharvest handling techniques for okra and garden eggs is consistent with work by Ampomah et al. (2022) and Nartey (2011), indicating that education enhances awareness and implementation of better postharvest methods, especially for perishables like okra. Additionally, the relationship between gender and utilization of postharvest techniques indicated potential gendered patterns in technology use or crop choice. This mirrors broader findings in sub-Saharan Africa, where gender norms influence who adopts what technology (Workneh, 2014; Aworh, 2008).

The use of packaging among traders is consistent with earlier findings by Kitinoja et al. (2018), who emphasized that appropriate packaging is essential for minimizing mechanical damage, enhancing market value, and extending the shelf life of horticultural produce. However, as noted by Olayemi et al. (2012), many smallholder farmers face challenges in accessing affordable and appropriate packaging materials, which limits the broader adoption of improved postharvest practices. The relatively low uptake of packaging among traders marketing garden eggs may reflect factors such as limited awareness, financial constraints, and a lack of incentives to invest in postharvest technologies. Furthermore, studies by Kader (2013) and FAO (2020) observed that traders often prioritize rapid turnover over investment in postharvest handling technologies, particularly under conditions of high market demand. Inadequate infrastructure, including the absence of cold chain systems and proper storage facilities, remains a significant barrier to effective postharvest management in many developing countries.

For cocoyam leaves, which have delicate tissues and high respiration rates, deterioration can begin within hours of harvest. Without interventions such as chilling or dehydration, yellowing, wilting, and microbial rot occur rapidly (Bua et al., 2020). Similarly for turkey berries, with their thin skins and high surface-to-volume ratio, they are highly prone to mechanical damage and dehydration (Acedo, 2010). Such poor handling not only shortens shelf life but also increases microbial loads and safety risks. The consistency in poor handling practices across both farmers and traders suggests systemic weaknesses in postharvest management, including low awareness, limited training, and lack of access to affordable technologies. Traders, who play a key role in aggregation and market distribution, are constrained by similar challenges, particularly inadequate infrastructure at transit and retail points (Kikulwe et al., 2018). The absence of integrated postharvest strategies among actors along the chain perpetuates losses and restricts the competitiveness of indigenous vegetables in both local and regional markets.

4.3.2 Challenges hampering the utilization of postharvest techniques

The study reveals significant challenges to the adoption of postharvest techniques and technologies among farmers and traders cultivating indigenous vegetables in Ghana's middle belt. These challenges have far-reaching implications for postharvest deterioration, shelf-life extension, and overall postharvest losses, particularly for highly perishable crops under study.

A key finding is the lack of knowledge and technical capacity among both farmers and traders, which remains a foundational barrier to effective postharvest management. Without sufficient training in handling, packaging, and temperature control, actors across the value chain are unable to implement even basic measures to reduce spoilage (Kitinoja and AlHassan, 2012; FAO, 2013). This knowledge gap perpetuates reliance on traditional, often inadequate practices that accelerate physiological deterioration, microbial contamination, and nutrient loss.

The high cost of adoption was reported by only a small proportion of farmers in Eastern and Ahafo, with no respondents in Bono East citing this challenge. This is consistent with a study by Mujibha et al. (2021) that indicates that cost is not always the primary barrier to adoption, especially when farmers perceive the benefits to outweigh the expenses. Although the initial investment in improved storage and processing technologies can be high, farmers who understand the long-term benefits are likely to adopt them (Abass et al., 2014). This also aligns with Kitinoja et al. (2018), who found that in cases where cost was not a significant challenge and farmers had access to financial support or lower-cost alternatives such as traditional storage techniques, adoption was feasible despite constraints.

Farmers and traders often operate within resource-constrained environments and cannot afford essential tools such as ventilated crates, cold storage units, or moisture-proof packaging. As noted by Kader (2005), the absence of temperature and humidity control mechanisms dramatically shortens the shelf life of fresh produce, particularly in tropical climates. In Ghana, such conditions result in rapid wilting, yellowing, and decay, especially for cocoyam leaves, which has high moisture content and respiration rates (Bua et al., 2020; Osei-Akoto et al., 2020).

A preliminary economic assessment suggests that the adoption of even basic postharvest technologies offers notable cost–benefit advantages for smallholder farmers and traders of indigenous vegetables. Technologies such as sun drying, sorting, packaging in improved crates, and use of evaporative cooling chambers have relatively low initial investment costs but can significantly reduce postharvest losses, which often range between 30–50% for perishable crops in Ghana (FAO, 2017; Affognon et al., 2015).

For example, the use of simple sorting and grading methods can improve market price margins by 10–30% due to enhanced visual appeal and uniformity (Acedo, 2010). Similarly, packaging using ventilated plastic crates, at a cost of GHS 15–20 per crate, can reduce physical damage and spoilage during transportation by up to 40% compared to traditional woven baskets (Kader, 2005; Osei-Asare et al., 2011). These savings in postharvest losses can translate into increased net revenues, particularly during peak harvest periods when market gluts are common.

Furthermore, sun drying of okra and turkey berries, can extend shelf life by several months, allowing for off-season marketing when prices are higher. This seasonal price arbitrage improves income stability for traders and processors (Reardon et al., 2003).

Market-related constraints, including poor infrastructure and low economic returns, discourage investment in postharvest improvements. Where farmers cannot reliably access premium markets or receive adequate compensation for quality produce, they are less motivated to adopt new technologies (Affognon et al., 2015). Traders, meanwhile, face challenges in handling bulk quantities under unsanitary and space-limited conditions in open-air markets, and this increases the risk of microbial spoilage and food safety issues (Ndiaye et al., 2021). The lack of cold storage in these environments further accelerates deterioration, leading to frequent product rejection and economic losses. Poor infrastructure, particularly in rural areas, constrains farmers' ability to store, transport, and market agricultural produce effectively (Food and Agriculture Organization of the United Nationsm 2020). Mrema and Rolle (2002) highlight the critical role of cold chain systems, processing facilities, and market linkages in minimizing postharvest losses. In regions characterized by poor road networks, limited storage capacity, and unreliable electricity, farmers face significant challenges in maintaining the quality of their produce, resulting in elevated levels of spoilage and economic loss. The lower proportion of respondents in Ahafo reporting infrastructure-related challenges may indicate comparatively better access to infrastructure or the availability of alternative mechanisms, such as cooperative networks or government support programs, to mitigate storage and transportation constraints (Mujibha et al., 2021). Many smallholder farmers in Ghana lack access to modern storage infrastructure, such as cold storage units, which are critical for preserving vegetable freshness (Afful-Koomson and Fonta, 2015; Fosu et al., 2025). As a result, farmers and traders are often compelled to sell their produce under unfavorable conditions, leading to lower prices and reduced income. The absence of proper storage facilities exacerbates postharvest losses by exposing vegetables to high temperatures and humidity, accelerating spoilage and decay.

Addressing these constraints requires a multi-pronged approach. First, capacity building through tailored extension services and hands-on training can equip farmers and traders with practical knowledge. Second, subsidies or financing schemes that lower the cost barriers to technology adoption can stimulate uptake among resource-poor actors. Third, investment in basic infrastructure, such as storage facilities and rural roads, can reduce postharvest transit losses and facilitate market access. Finally, fostering public–private partnerships to develop and distribute context-appropriate postharvest innovations will be vital for scaling interventions sustainably. Unless these systemic challenges are addressed, indigenous vegetables will continue to suffer from short shelf life, poor marketability, and significant postharvest losses and ultimately undermining their contribution to Ghana's food and nutrition security goals.

Experiences from other countries provide useful models for improving postharvest outcomes in Ghana's indigenous vegetable value chains. In Kenya, the Postharvest Training and Services Center (PTSC) initiative, supported by the World Food Logistics Organization (WFLO) and USAID, demonstrated the effectiveness of simple, scalable interventions such as, shade net structures, zero-energy coolers, and training in hygienic handling, to reduce postharvest losses of horticultural produce by up to 30% (Kitinoja, 2010). These interventions were tailored to smallholder farmers and incorporated capacity-building sessions for local extension agents, resulting in improved adoption rates and reduced deterioration of leafy greens and fruits. In India, the National Horticulture Mission (NHM) invested in farmer field schools and rural packhouse infrastructure, along with promoting cost-effective technologies like ventilated plastic crates and on-farm solar dryers. A study by Roy and Pal (1994) showed that training combined with access to simple infrastructure significantly reduced postharvest loss in perishable vegetables by up to 35%. These approaches prioritized local adaptation, public–private partnerships, and demonstration effects to encourage broader uptake.

These examples suggest that postharvest loss reduction does not always require high-tech or capital-intensive solutions. Instead, integrated interventions that combine practical demonstrations, local infrastructure, and farmer-trader training, especially in sorting, grading, drying, and cooling, can yield considerable improvements. Drawing lessons from these contexts, Ghana could adopt a decentralized model of postharvest service centers or mobile extension units focused specifically on indigenous vegetables. This would ensure that interventions are locally relevant and accessible to smallholders and informal traders, who form the bulk of the actors in this value chain.

5 Conclusion

This study provides vital insights into the postharvest handling practices, technologies, and challenges faced by smallholder farmers and traders of indigenous vegetables in Ghana's middle belt. The findings highlight that postharvest deterioration and losses are influenced by a complex interplay of socio-demographic characteristics, limited infrastructure, and uneven access to knowledge and technologies. While farmers were more likely to engage in production-related postharvest practices, traders especially women, played a central role in marketing but were constrained by poor access to improved storage and handling facilities.

The study also revealed significant geographic disparities in technology adoption, emphasizing the need for location-specific interventions. Despite the high perishability of indigenous vegetables like okra, garden eggs, turkey berries, and cocoyam leaves, the adoption of improved postharvest technologies remains limited. This contributes to reduced shelf life, quality deterioration, and food and income insecurity, especially for vulnerable groups.

6 Recommendations

To address the persistent challenges associated with postharvest deterioration and losses of indigenous vegetables, several strategic actions are recommended. First, there is a need to strengthen postharvest training programs targeted at both farmers and traders. These programs should be gender-responsive and tailored to the needs of women and youth, who are key actors in the indigenous vegetable value chain. Practical and participatory training approaches will help improve awareness and adoption of appropriate postharvest technologies and practices. Second, the promotion and scaling of low-cost, context-appropriate postharvest innovations, such as improved packaging materials, and solar drying technologies should be prioritized. These technologies are particularly suitable for rural and peri-urban areas where infrastructure is limited, and can contribute significantly to extending shelf life and reducing quality deterioration.

Third, policy and investment frameworks must be deliberately inclusive, particularly in supporting the role of women in indigenous vegetable marketing. Access to infrastructure such as market stalls, processing spaces, and cold storage facilities should be expanded to empower women traders and reduce their postharvest losses. Enhancing rural infrastructure and market linkages is critical. Improved road networks, transportation services, and cold chain logistics can minimize transit-related damage and ensure timely delivery of produce to markets in good condition.

Youth engagement in the indigenous vegetable sector should be encouraged since they are essential for long-term sustainability. This can be achieved through interventions that integrate digital tools, agro-processing, and entrepreneurship training to make the sector more appealing and viable for younger populations. Lastly, future research should incorporate experimental designs that compare traditional postharvest handling practices with improved or modern technologies. Such comparative studies would enable a more rigorous evaluation of the effectiveness, cost-efficiency, and impact of interventions on postharvest loss reduction, shelf-life extension, and produce quality. Including a control or benchmark group will also allow for stronger causal inferences and provide evidence to guide policy and investment decisions in the indigenous vegetable value chain.

Data availability statement

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

Ethics statement

The studies involving humans were approved by University of Ghana's College of Basic and Applied Sciences Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

GE: Writing – review & editing, Formal Analysis, Software, Project administration, Supervision, Methodology, Conceptualization, Visualization, Investigation, Validation, Data curation, Funding acquisition, Resources. RB: Methodology, Data curation, Writing – original draft, Formal Analysis, Software. SA: Data curation, Writing – original draft, Investigation.

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Conflict of interest

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

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Supplementary material

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