

Awareness of Stored-Grain Pests and Their Control among Consumers and Sellers in Sri Lanka

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ABSTRACT

Stored-product insect pests are a major cause of post-harvest losses globally and in Sri Lanka, where favorable climatic conditions and suboptimal storage practices exacerbate infestations. This study assessed the knowledge, attitudes, and practices (KAP) of household grain consumers and grain sellers (Retail stores, supermarkets and warehouses) regarding stored-grain pests and their management across four districts in Sri Lanka (Ampara, Kandy, Gampaha and Colombo). A structured questionnaire survey was conducted among 400 consumers and 120 sellers using purposive sampling, followed by KAP-based analysis. Results indicated that overall knowledge

levels among both consumers and sellers were low, with 63% and 77% respectively categorized as having poor knowledge. However, 67% of the consumers reported good storage practices, particularly the use of plastic containers and regular cleaning. Poor storage practices by sellers (96% poor practices), such as use of synthetic and gunny bags, often placed on floors, increased vulnerability to pest infestations. Attitudes towards pest control especially use of plant-based pest control methods were largely negative (82% consumers and 80% sellers. Chemical control methods were rarely used at household level but occasionally applied in warehouses, such as Actellic 50EC (pirimiphos-methyl) raising safety concerns. The findings for the first time revealed significant gaps in awareness and pest management practices, particularly at the commercial storage level in Sri Lanka. The study highlights the need for targeted awareness programs, improved storage practices, and integration of indigenous and environmentally friendly pest control strategies to enhance food security and reduce grain losses in Sri Lanka.

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INTRODUCTION

Globally, insect pests represent one of the most significant biotic constraints affecting grain production and storage systems, accounting for an estimated 30–40% reduction in total grain yields (Abass *et al.* 2014, Boxall 2002, Tapondjou *et al.* 2002). In Sri Lanka, more

than 80% of post-harvest losses of stored grains under warehouse conditions have been attributed to insect pest infestations (Wasala *et al.* 2016 ; Palipane 2001). The country's wet tropical climate, characterized by high temperature and humidity throughout the year, creates an environment highly conducive to insect breeding, growth and survival. While environmental factors such as temperature and humidity are beyond human control, human intervention in storage management can be standardized and optimized. Proper sanitation, improved storage structures, moisture control, routine inspection, and timely pest detection are critical preventive measures, where their effectiveness largely depends on the awareness, attitudes and practices of individuals involved in grain storage and trade (Talukder 2009).

Given the substantial economic losses, health concerns, and sustainability challenges associated with current pest management practices, it is crucial to assess existing knowledge and practices related to stored product pest control. Therefore, the proposed study aims to fill this research gap by determining the knowledge, attitudes, and practices (KAP) of household grain consumers, and grain sellers of local retail stores, and warehouses in Sri Lanka regarding the grain storage methods, and pest management strategies.

MATERIALS AND METHODS

Survey Sites

A questionnaire survey was conducted in four districts of Sri Lanka (Fig. 1): Ampara and Kandy, both major agricultural areas representing rural and urban production zones respectively, and Gampaha and Colombo, selected as urban consumer regions where grains are predominantly stored and marketed rather than produced.

Questionnaire Development

Two separate questionnaires were developed: one for household grain consumers, and another for sellers in retail stores (local grocery shops and supermarkets) and warehouses. Both questionnaires included a core set of questions addressing socio-demographic char-

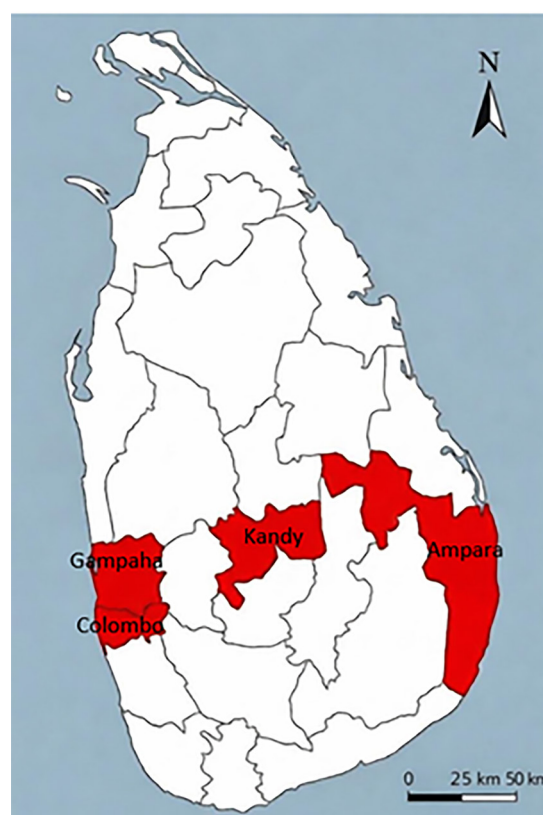


Fig. 1. Map showing districts, Ampara, Gampaha, Colombo and Kandy, where questionnaire survey was conducted.

acteristics, grain storage practices, and observations related to pest infestations, and storage facilities. In addition there were some questions specific to each group. The questionnaires consisted of both closed-ended and open-ended questions, structured into sections to assess knowledge, attitudes, and practices (KAP).

Survey Implementation

Ethical clearance for the study was obtained from the Postgraduate Institute of Science, University of Peradeniya, Sri Lanka (No. CEC-PGIS-2024-05). The questionnaire survey was conducted between 2023 and 2024. A total of 100 household consumers and 30 grain sellers (local grocery shops, supermarkets, and warehouses) were surveyed from each district through face-to-face semi-structured interviews (Total of 400 households and 120 sellers) to ensure

Table 1. Scoring scheme for Knowledge, Attitude, and Practice (KAP) assessment on stored-product pest management among grain users.

Survey Question	Survey response & Scoring Criteria
Knowledge	
Have you observed any developmental stage of insect pests in seeds when you buy them ?	Yes = 1 / No = 0
If you have observed any stage of their life cycle, which stages did you observe ?	Eggs = 1 / Pupae = 1 / Adults = 1 (Each correctly identified stage scores 1 point)
How long can you store grains without any pest attack ?	More than one month = 0 / < One week = 1 / One week to two weeks = 2 / Two weeks to one month = 3 Good knowledge = 6–7 ($\geq 70\%$) / Moderate knowledge = 4–5 (50–69%) / Poor knowledge = 0–3 (< 40%)
Overall Knowledge Score	
Attitude	
Do you believe in any traditional method to control these pests ?	Yes = / No = 0
What are those methods you have used to control stored-product pests ?	0 = No valid method mentioned / 1 = At least one valid method mentioned / 2 = Two or more valid methods mentioned
Overall Attitude Score	
Practices	
What are the methods you use to remove insect stages during grain storage ?	No method = 0 / Using insecticides = 1 / Hand picking = 2 / Air drying = 3 / Destroying seeds = 4
How long do you store grains in the house ?	One–two weeks = 3 / Two weeks–one month = 2 / > One month = 1
What storage items do you use ?	Plastic containers/bottles = 3 / Polyethylene bags/synthetic sacks = 2 / Gunny bags = 1
Place of storage	Above ground level = 2 / Floor storage = 1
Overall Practice Score	Good practice = 9–18 / Moderate practice = 5–8 / Poor practice = 0–4

Table 2. Scoring scheme for Knowledge, Attitude, and Practice (KAP) assessment on stored-product pest management among grain sellers.

Question	Response Options and Scoring
Knowledge	
According to your knowledge, how long does it take for pests to appear in grains after storage ?	< One–two weeks = 3 / Two weeks–one month = 2 / > One month = 1 / Other = 0
According to your knowledge, where do insect pests attack stored seeds ?	Warehouse = 2 / Storeroom (retail sellers) = 1
Overall Knowledge Score	Knowledgeable ≥ 3 / Poor knowledge < 3
Attitude	
Are you satisfied with the pest removing method you use ?	Yes = 1 / No = 0
Do you believe in the effectiveness of plant-derived products to control insect pests ?	Yes = 1 / No = 0
Overall Attitude Score	Positive attitude ≥ 1 / No belief / no knowledge = 0
Practice	
How are the grains stored ?	Grains isolated from other items = 1 Randomly stored with other items = 0
How long do you store grains in the storeroom ?	< Two weeks = 4 / > One month = 3 / > Six months = 2 / > One year = 1
What methods are used to control emerging pests ?	Plant products = 3 / Other traditional methods = 2 / Insecticides = 1
Overall Practice Score	Good practice = 6–8 / Moderate practice = 3–5 / Poor practice = 1–2

Table 3. Classification thresholds for the Knowledge, Attitude, and Practice (KAP) component scores.

Component	Consumers			Consumers		
	Score range	Max score	Classification	Score range	Max score	Classification
Knowledge	0–7	7	Good knowledge = 6–7 Moderate knowledge = 4–5 Poor knowledge = 0–3	0–5	5	Knowledgeable ≥ 3 Poor knowledge < 3
Attitude	0–3	3	Positive attitude = 2–3 Neutral attitude = 1 Do not believe = 0	0–2	2	Positive attitude ≥ 1 No belief = 0
Practice	0–18	18	Good practice = 9–18 Moderate practice = 5–8 Poor practice = 0–4	0–8	8	Good practice = 6–8 Moderate practice = 3–5 Poor practice = 1–2

adequate representation of grain storage practices across different settings. Local retail grocery shops constituted the majority of businesses surveyed across all districts (Ampara 74%, Gampaha 87%, Colombo 90%, Kandy 92%), whereas supermarkets were less common, ranging from 7% in Colombo to 11% in Ampara. Respondents were selected using a purposive sampling approach to ensure broad representation of storage practices and pest control experiences across all the study localities.

Data Analysis

Data were analyzed to calculate the percentages of participants classified as having “good” or “poor” levels of knowledge, attitudes and practices (KAP). The key questions and the KAP scores, which reflect the knowledge, attitudes, and practices of consumers and sellers are presented in Table 1 and 2 respectively. The scoring and classification of knowledge, attitude, and practice (KAP) were based on percentage-based cut-off values adapted from Bunket *et al.* (2026) (Ta-

ble 3). All collected data were compiled and analyzed using Microsoft Excel (version 2108). Significant differences and associations were analyzed using Chi-square tests using Minitab statistical software (Version 19.1).

RESULTS AND DISCUSSION

Sociodemographic information

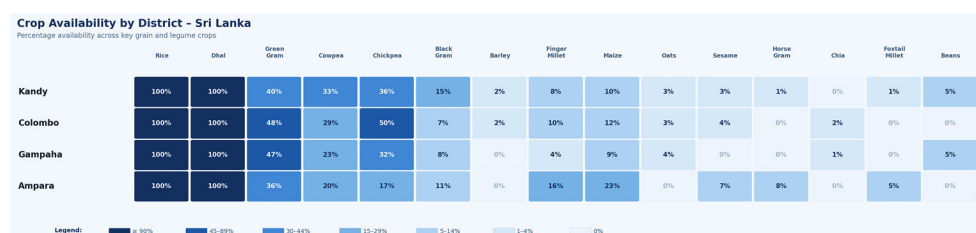
The distribution of sociodemographic information across the four districts are summarized in Table 4. Educational attainment was relatively high among both consumers and sellers where, more than 74% had completed the secondary or tertiary level education. Overall, the majority of the consumer population consisted middle-aged (>35 years) females with at least secondary-education. No specific age distribution pattern was observed among sellers; however, male respondents predominated in Ampara and Colombo, while female respondents were more prevalent in Gampaha and Kandy.

Table 4. Demographic profile of survey respondents by district, including gender, age, and education level.

District	Gender (%)				Age (%)				Education level (%)					
	Female		Male		35–55 y		>55 y		Primary		Secondary		Tertiary	
	C	S	C	S	C	S	C	S	C	S	C	S	C	S
Colombo	98	40	2	60	63	63	26	7	1	-	85	97	14	3
Gampaha	97	87	3	13	47	50	21	40	-	-	83	100	17	-
Kandy	95	80	5	20	65	48	5	12	1	-	85	100	14	-
Ampara	87	19	13	81	18	67	60	15	3	-	88	100	9	-

Note- C- Consumers, S- Sellers

Percentages are presented only for the two age groups included in the analysis.



Note. Cell shading intensity reflects the percentage of respondents consuming each grain type ; darker blue indicates higher consumption. Values represent the percentage of surveyed households (% respondents) in each district.

Fig. 2. Percentage of household grain users consuming 15 selected grain types; rice, dhal, green gram, cowpea, chickpea, black gram ('undu'), barley, finger millet ('kurakkan'), maize, oats, foxtail millet ('meneri'), horse gram ('kollu'), sesame ('thala'), beans and chia across four districts.

Knowledge, attitudes and practices

Households across the four districts reported regular consumption of 15 types of grains and seeds, while approximately 20 different types of grains and seeds were sold by retail grocery stores and supermarkets. Rice and dhal were universally consumed and sold across all districts, confirming their role as staple foods in Sri Lankan diets, followed by green gram and chickpea. These results support previous findings on staple dietary patterns in Sri Lanka (Silva *et al.* 2020).

Variation in grain use across districts appeared influenced by local dietary preferences, cultivation patterns, urbanization, and socioeconomic factors. Kandy which is considered as an urban agricultural

area, exhibited the highest diversity of grain consumption, with >90% of respondents reporting the use of 14 grain types. Gampaha and Ampara showed comparatively lower diversity, with only 11 of the listed grains being utilized. Certain grains showed district-specific consumption patterns. For instance, oats, beans, barley and chia were not consumed by respondents in Ampara, whereas horse gram was frequently consumed almost exclusively in this district (Fig. 2). Further, Ampara showed higher utilization of foxtail millet, horse gram and sesame, consistent with its role as key rural agricultural area (Bandula and Nath 2020).

Consumers generally stated that the purchased grains are contaminated by pests regardless of the

Table 5. Summary results of KAP analysis for the household grain consumers (n = 100 respondents per district), and retail grain stores and warehouse operators (n = 120) interviewed from the four districts.

Attribute	Sections	Good (%)		Moderate (%)		Bad (%)	
		C	S	C	S	C	S
Knowledge	Ampara	3	18.52	36	0	61	81.48
	Gampaha	7	36.67	34	0	59	63.33
	Colombo	10	26.67	31	0	59	73.33
	Kandy	4	12	22	0	74	88
	Overall	6	23.47	30.75	0	63.25	76.54
Attitude	Ampara	15	18.52	3	0	82	81.48
	Gampaha	13	33.33	7	0	80	66.67
	Colombo	9	20	6	0	85	80
	Kandy	12	8	7	0	81	92
	Overall	12.25	19.96	5.75	0	82	80.04
Practice	Ampara	47	7.41	51	48.15	2	44.44
	Gampaha	78	0	22	16.67	0	83.33
	Colombo	72	6.67	27	20	1	73.33
	Kandy	70	0	28	40	2	60
	Overall	66.75	3.52	32	31.21	1.25	65.28

Note- C- Consumers, S- Sellers

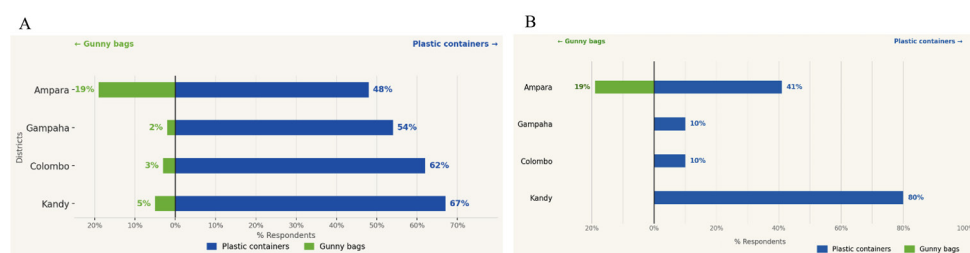


Fig. 3. Comparison between the utilization of plastic containers and gunny bags as storage items, by (A) grain consumers (n=100 consumers per district) (B) Vendors, from the selected households in the four districts and (n= 30 vendors per district)).

source of purchase, including supermarkets and local grocery stores. However, according to KAP analysis regardless of their educational level, 63% and 77% of consumers and sellers, were respectively having poor knowledge and awareness on stored-product pests (Table 5). This suggests that general education does not necessarily translate into specific knowledge on pest management, indicating a gap in targeted awareness. Despite limited knowledge, practice outcomes were relatively positive among consumers. Overall, 32% of consumers demonstrated moderate practices, and 67% exhibited good practices. In contrast, majority of the sellers (65%) were showing poor practices, highlighting vulnerabilities in commercial storage (Table 5).

Among practices the grain storage item and location significantly influence infestation risk. Overall, 58% of all the consumers used plastic containers for grain storage, with the highest usage in Kandy and Colombo (Fig. 3A). This is a good practice, as plastic containers not only reduce pest entry but also limit oxygen and moisture exposure, thereby extending storage life and maintaining grain quality (Dowell and Dowell 2017). Other storage materials, including synthetic sacks, polythene bags, and gunny bags, were used significantly less frequently ($\chi^2 = 27.352$, $p < 0.001$), with overall usage rates of 13%, 9%, and 7%, respectively. Importantly, when considering only gunny bag usage, it is most prominent and significant in Ampara (19%) ($\chi^2 = 15.085$, $p = 0.000$), reflecting its character as a traditional rural area (Fig. 3A). Majority of respondents from all the districts, i.e. 92% in Colombo, 77% in Gampaha, 69% in Kandy, and 67% in Ampara, stored grains above ground, either in closed cupboards, or open racks. Among all sites, Am-

para reported the highest percentage of floor storage (32%; $\chi^2 = 7.200$, $p = 0.007$), indicating comparatively poorer storage practices among consumers in this study area, as floor-level storage, especially common in Ampara, increases vulnerability to pests, moisture, and dust, whereas elevated storage in cupboards or racks provides moderate protection.

Sellers reported using a combination of storage materials, including synthetic bags, plastic containers, gunny bags, and, to a lesser extent, polythene bags, and the use of package material was associated with the district ($\chi^2 = 74.51$, $p = 0.000$). For instance, almost all the vendors from Gampaha and Colombo used synthetic bags for grain storage likely due to greater availability and convenience in urban areas, whereas Ampara reported the lowest usage (59%). In contrast, 80% of Kandy population used plastic containers, which is a very safe alternative compared to all the others (Fig. 3B). Similar to households, Ampara which is a rural area relied more heavily on pure gunny bags (19%) for grain storage, reflecting local practices and limited access to synthetic alternatives. Overall, the most common practice by all the vendors across all study locations was placing these synthetic or gunny bags directly on the floor, primarily for convenience despite the associated risk of pest infestation.

A strong association was observed between the time of detection of pest stages in the grains stored in house with the district ($\chi^2 = 15.244$, $p = 0.002$). Majority of Colombo, and Gampaha, reported earlier detection of pests, with approximately 38% observing pest stages within two weeks to one month after purchase (Fig. 4A). Interestingly, Gampaha reported

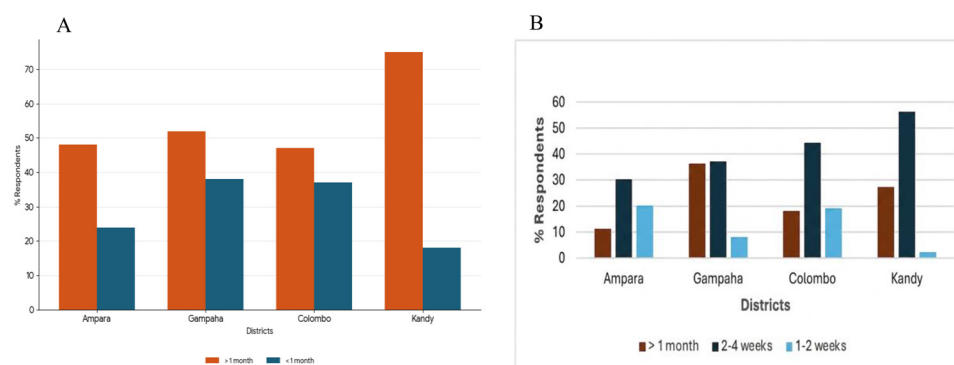


Fig. 4. (A) Pest detection time of stored grains, and (B) Grain storage duration, by consumers in the selected four districts (Some respondents either did not respond or gave unclear responses. These entries were excluded from the analysis, which explains why the total percentage does not sum to 100%).

storing grains for more than one month in their households (Fig. 4B) regardless of the fact that the pest stages are detected in their grains in less than one month. Although majority of the participants from Kandy (58%) stored grains for less than one month in their houses, 75% of them stated the ability to store grains for more than one month, without detecting any symptoms of pest attack (Fig. 4). However, retail vendors reported longer storage durations (two to six months, sometimes over a year), increasing pest risk.

In Kandy, the high prevalence of plastic container use in both households and shops was associated with delayed pest detection. In contrast, in Ampara, the lower use of plastic containers and greater reliance on gunny bags and floor storage may contribute to earlier pest detection. Furthermore, the limited barrier effect of synthetic bags, particularly when stored on the ground, may also explain earlier pest detection in Gampaha and Colombo. As reported by Andreadis and Athanassiou (2017), refrigerated storage, is effective for high-value or sensitive grains but was rarely used in the present study (<5% in households, none

in shops/warehouses) due to cost and accessibility constraints. Although, modern storage systems, such as silos, hermetic storage, and controlled-atmosphere facilities, provide better protection, the high-cost limited adoption of these methods by small-scale vendors (Nwaigwe 2019 ; Sekumade and Oluwatayo 2009).

Especially vendors expressed concern regarding the risk of infestation in newly stored grains, which they attributed to contamination from previously stored products or the presence of pest eggs within storage environments. Therefore, cleaning of storage areas via sweeping were widely practiced by both groups where 56% of consumers and 75% of sellers stated that these practices enabled safe grain storage for extended periods. Additional practices included vacuuming, mopping, and application of soap (Table 6). Furthermore, infested grains were primarily destroyed by burning (36% of consumers and 41% of sellers), followed by disposal via garbage collection (13% of consumers and 35% of sellers) and burying (8% of consumers and 16% of sellers). These practices represent appropriate measures adopted by both

Table 6. Comparison between cleaning of storage areas and discarding methods of infected grains by consumers (n = 400) and sellers (n = 120) surveyed across the four districts.

Survey group	Storage area cleaning methods (%)			Disposal methods of contaminated grains (%)					
	Sweeping	Wiping	Mopping	Burning	Garbage trucks	Burying	Producing compost	Animal food	Returning
Consumers	56.75	28.75	9.25	35.75	13.25	7.5	6.25	1.75	—
Sellers	75	0.92	21.45	41.07	34.82	16.07	0	6.25	0.89

consumers and sellers to prevent further contamination (Table 6).

None of the consumers reported using insecticides, where a limited number of warehouse operators reported using chemical fumigants, such as Actellic 50EC (pirimiphos-methyl), applied through fogging to control storage pests, raising health concerns if misused (Otieno and Alwenge 2020). Longer storage with minimum pest attack by vendors might be associated with the use of Actellic 50EC. Nearly 98.5% of consumers perceived plant-based pest control methods as ineffective, and most vendors considered this as a pest control method appropriate for household use but impractical for large-scale commercial storage. Among the few respondents who employed plant-based materials, commonly used substances included ash, cinnamon, neem leaves, Ceylon crisp leaves, red chili, garlic, clove, and lime leaves. A district-specific practice in Ampara involved the addition of dried husks of areca nuts, which are believed to deter grain pests. These results were supported by the KAP analysis where the attitudes toward traditional control methods were generally poor (>80% in both groups) across all districts, highlighting a critical gap in pest management especially at the retail and warehouse level (Table 5). Comparatively, Ampara (15%) had the highest proportion of positive attitudes, where as, negative attitudes towards the use of plant-based products were most prevalent in urban areas, i.e. Colombo (85%) and Gampaha (80%).

Retail sellers and warehouse operators reported several challenges related to grain protection, including inadequate storage conditions, limited government support, and cross-infestation among different grain types. Respondents also indicated limited knowledge regarding the timing or application of insecticides during pre- or post-harvest stages. Concerns were raised about the quality of imported rice, particularly regarding the presence of chemicals in sealed packets, which were reported to emit noticeable odors upon opening.

Geographical variation also influenced outcomes of this study. Consumers from urban districts Colombo, Gampaha, and Kandy demonstrated comparatively higher levels of good practices than those from rural cultivating district Ampara. This difference may be

attributed to better access to information, improved storage infrastructure, and greater exposure to pest control measures in urban settings, whereas rural agricultural areas may rely more on traditional practices. Furthermore, differences between stakeholder groups were evident. Retail grain sellers showed lower levels of knowledge and poorer practices compared to household consumers, despite their direct involvement in grain handling. This highlights a lack of structured training or awareness programs targeting commercial actors in the grain supply chain.

Although the purposive selection of four study sites representing urban and, rural areas allowing meaningful comparison between grain consumers and vendors, it may not fully reflect the diversity of storage practices and pest management behaviors across all regions of Sri Lanka, thereby limiting the generalizability of the results. Additionally, although different stakeholder groups were included, the relatively smaller sample size of retail shops compared to households may limit detailed subgroup comparisons.

CONCLUSION

This study highlights significant differences in grain storage and pest-management practices among households and grain sellers across the four districts of Sri Lanka. Although consumers generally demonstrated better practices, knowledge and awareness of stored-product pests remained limited, particularly among sellers. Proper storage methods, such as using plastic containers and elevated storage, were associated with reduced pest risk, while floor storage and traditional storage materials increased vulnerability to infestation. The findings emphasize the need for targeted awareness and training programs, especially for grain sellers and warehouse operators, together with improved storage facilities and safe, practical pest-management strategies to reduce grain losses and maintain grain quality.

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