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Research article

IMPACT OF POST-HARVEST TECHNOLOGY ADOPTION ON THE WELL-BEING OF PEPPER FARMERS IN KEGALLE, SRI LANKA

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ABSTRACT

Pepper is the most widely consumed spice globally and was historically the first to be traded internationally. Sri Lanka, renowned for its high-quality spices, has recently experienced a decline in pepper quality. Ensuring high standards in pepper production is essential for competitiveness in the global market, which can be achieved through the adoption of modern post-harvest processing technologies. This study investigates the determinants influencing the adoption of these technologies and their subsequent impact on the well-being of farmers in the Kegalle District. The technologies assessed herein include threshing machines, blanchers, and drying equipment. Data were collected using a pre-tested questionnaire and structured interviews, involving 47 farmers who adopted the technologies and 50 non-adopters, selected through stratified random sampling. Analytical methods included descriptive statistics, the Mann-Whitney U test, and binary logistic regression. The results obtained indicate that factors such as internet access, credit accessibility, production costs, and proximity to markets significantly influence the decision to adopt technology. Conversely, socio-economic variables like farming experience and income levels were found to have no significant effect. The farmers who regularly interacted with extension officers and utilized online resources were more likely to adopt the technologies. Differences in satisfaction between the adopters and non-adopters were observed only relative to training programs, whereas other extension services showed no significant variations. The study also found that over 70% of the adopters reported increased income, savings, and physical assets, along with a reduced household workload. The findings suggest that the adoption of modern post-harvest processing technologies substantially enhances the overall well-being of pepper farmers in Sri Lanka.

Key words:
pepper farmers, post-harvest processing, technology adoption, farmers' wellbeing

Abbreviations:
ASMEC - Annual Symposium on Export Agricultural Crops; COP - cost of production; DEA - Department of export agriculture; DS - Divisional Secretariat; EAC - export agricultural crop; GDP – Gross Domestic Production; OXFAM - Oxford committee for famine relief

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INTRODUCTION

Sri Lanka is a country with a strong agricultural foundation, with the sector contributing 8.3% to the national Gross Domestic Production (GDP) in 2020 (Central Bank of Sri Lanka, 2020). Black pepper, often referred to as the "King of Spices," is a historically significant crop originating from South India (Export Development Board, 2022). Historically known as "black gold," peppercorns were highly valued and extensively traded from the Malabar region

in India. Nowadays, the leading global producers of pepper include Vietnam, Indonesia, Malaysia, India, and Brazil (Disna and Ranawaka, 2018).

In Sri Lanka, pepper ranks as the second most important export agricultural crop (EAC), serving as a primary income source for numerous farmers (Disna and Ranawaka, 2018). The country cultivates both hybrid cultivars, such as "Panniyur 01," and indigenous cultivars, including "MB 12" and "GK 49." Additionally, new hybrids introduced by the Department of Export Agriculture (DEA), such as "Dingirala," "Kohokumburerala," and "Bootewerala," are also cultivated. Pepper is primarily grown in six provinces within the wet and intermediate zones of the country. Ensuring high-quality pepper is vital for maintaining competitiveness in the export market, which largely depends on efficient harvesting and post-harvest processing techniques. Globally, adopting innovative technologies for agricultural production and post-harvest processing has become critical for enhancing the quality of agricultural products. For Sri Lanka, which has substantial agricultural potential, the adoption of these modern technologies is crucial. To support this, the DEA has implemented the "Post-Harvest Quality Improvement through Appropriate Technology" program, aiming to improve the quality of export crops. This initiative focuses on maintaining high product standards for international markets, promoting diversification and value addition, and enhancing marketing efforts (Department of Export Agriculture, 2022). The program spans 17 districts, including Kegalle, a key pepper-producing region.

The adoption of new technologies is a pivotal solution to the challenges faced in pepper processing. Maximizing agricultural production and processing potential depends significantly on the innovative capacity of agricultural stakeholders, particularly farmers. Their ability to adopt new technologies is influenced by various factors, including access to and the capacity to implement these technologies (Abunga et al., 2012). Enhancing pepper quality and processing efficiency through appropriate technologies is essential for boosting exports and generating foreign exchange, which is particularly important given Sri Lanka's current economic challenges. Understanding the factors influencing the adoption of new technology is critical for promoting sustainable agricultural practices. Equally important is identifying how farmers seek information and the sources they rely on for post-harvest processing technologies. However, research on the determinants of technology adoption among farmers remains limited, necessitating a closer examination of the key drivers, their impact on processing activities, and farmers' information-seeking behaviors.

This study aims to analyze the determinants of technology adoption and assess its impact on the pepper quality and farmers' livelihoods in Sri Lanka. By exploring these factors, the study seeks to provide valuable insights into enhancing pepper quality and improving processing efficiency through technological adoption. Such advancements could lead to increased pepper exports and significantly improve the economic status of Sri Lankan farmers. Sri Lankan pepper, renowned for its unique spicy taste due to piperine, has experienced a significant decline in quality due to inadequate post-harvest practices. As a result, countries like India and Pakistan buy Sri Lankan pepper at low prices, disregarding its quality, which leads to substantial economic losses. High-end European countries often reject low-quality pepper, further reducing the potential for foreign currency earnings. Improving the export quality of Sri Lankan pepper is crucial. Agricultural research and technological advancements in production play a key role in enhancing both productivity and quality (Challa et al., 2014). The Department of Export Agriculture has introduced new post-harvest processing technologies to improve pepper quality and enhance farmers' livelihoods. However, the factors influencing the adoption of these technologies and their impact on pepper quality and farmers' well-being remain empirically unexplored.

The broad objective of this study is to assess the determinants and impacts of new technology adoption on the post-harvest processing, farmers' livelihoods, and pepper quality in the Kegalle District. The specific objectives were to identify the factors influencing the adoption of new post-harvest processing technologies for pepper, to assess the impact of farmers' information-seeking behavior on technology adoption, and to evaluate the farmers' satisfaction with the extension services related to new post-harvest technologies among the adopters and non-adopters.

MATERIAL AND METHODS

The research followed a deductive and descriptive approach. A combination of survey and experimental strategies was employed. The survey method involved collecting data from individuals within a selected sample to generalize the findings to a larger population. A pre-tested, researcher-administered questionnaire was used for data collection. The questionnaire consisted of three sections: the first assessed the socio-economic factors and determinants influencing technology adoption; the second examined the impact of technology adoption; and the third evaluated the farmers' satisfaction with the existing extension services and identified gaps. The questionnaire included open-ended, close-ended, and Likert scale questions. Data were collected through telephone interviews and field visits to pepper farms in the study areas.

The research framework of this study was developed based on the literature review, and the conceptual framework is presented in Figure 1.

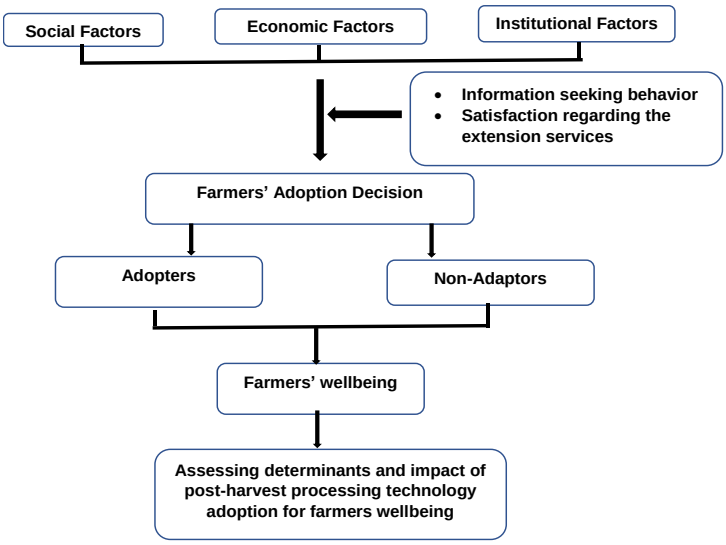

Figure 1. Conceptual framework of the study

Research Area

The Kegalle District was selected as the study location. The district comprises eleven Divisional Secretariat (DS) divisions. According to the Department of Export Agriculture (2022), Kegalle, Badulla, Ratnapura, Matale, Kandy, Monaragala, and Kurunegala are considered the major pepper-growing regions in Sri Lanka. The wet zone is highly suitable for pepper cultivation (Department of Export Agriculture, 2022), and Kegalle, being located within this zone, is recognized as a key pepper-producing area. In 2020, a total of 1,735 hectares were devoted to pepper in the Kegalle District (Department of Census and Statistics, 2014). The 2022 Census data reveal that the district has a population of approximately 898,000, with a significant proportion engaged in smallholder farming, including pepper cultivation. Conducting research in Kegalle allows for an in-depth examination of the challenges faced by these farmers, ensuring that the findings are relevant and practically applicable. Moreover, the Department of Export Agriculture (DEA) actively supports the pepper farmers in the district by introducing advanced agricultural technologies. A high concentration of farmers in Kegalle has adopted these technologies, making the district particularly suitable for studying post-harvest technology adoption in pepper production. Furthermore, the researcher resides in the Kegalle District, which facilitated data collection. The study specifically targeted farmers engaged in pepper cultivation. Among the total agricultural workforce in the district, 109,615 male and female farmers were involved in farming activities. Given the prevalence of pepper farming and the presence of technology-adopting farmers, Kegalle was deemed an ideal location for the study.

Figure 2. A map of the Kegalle District

The study focused on smallholder pepper farmers in the Kegalle District, categorized as technology adopters and non-adopters. The sampling frame comprised the farmers registered under the Department of Export Agriculture's subsidy program. Using judgmental sampling, four DS divisions with high technology adoption rates were selected: Rambukkana, Ruwanwella, Aranayake, and Mawanella. Given resource constraints, a stratified random sampling method was employed to ensure an adequate representation of both the adopter and non-adopter groups while addressing limitations related to time and budget. By targeting these specific segments, the study aimed to assess the impact of post-harvest processing technologies on the pepper cultivation practices in the region, providing valuable insights for agricultural development and policy formulation.

This study employed a sample size of 100 due to constraints such as limited time, long distances between the farmers, transportation challenges, financial limitations, the expectation of similar responses from most participants, and the focus on a few large subgroups for a general estimate. The primary data were collected using interviewer-administered questionnaires and structured interviews to address the specific research objectives. The questionnaire was structured into several sections according to the study objectives and comprised three main sections. The first section assessed the socio-economic factors and determinants influencing technology adoption, the second examined the impact of technology adoption, and the third evaluated the farmers' satisfaction with the existing extension services while identifying gaps. The questionnaire included open-ended, close-ended, and Likert scale questions. The primary data were collected from the selected sample of small-scale pepper farmers in the Kegalle District between February and April 2022. Data collection was conducted through telephone interviews and field visits to pepper farms. The researcher personally visited the fields to gather data. The secondary data were obtained from journal articles, government publications, conference proceedings of Annual Symposium on Export Agricultural Crops (ASMEC) in the DEA, annual reports, and statistical databases from Sri Lanka Customs and the Central Bank. Binary logistic regression was used to analyze the determinants of new technology adoption, the impact of farmers' information-seeking behavior on technology adoption, and the effect of technology adoption on farmers' livelihoods.

RESULTS AND DISCUSSION

Socioeconomic characteristics of the respondents

The socioeconomic characteristics of the participants in this study were assessed based on several factors, including gender, marital status, education level, occupation, land ownership, and annual farm income (Table 1). These variables were considered to provide a general classification of the farmer types.

Table 1. Socioeconomic characteristics of the respondents

Attribute	Adopters (%)	Non-Adopters (%)	Insights
Gender			
- Males	38	45	Most pepper farmers are males.
- Females	9	8	
Education Level	Higher (University degree/Postgraduate)	Generally good in both groups	Education was not a major factor in technology adoption.
Primary Occupation	32	29	Adopters showed a stronger commitment to farming.
Land Ownership	43	53	Land ownership was not critical for adopting technologies.
Marital Status (Married)	45	49	Unmarried adopters may have more financial flexibility for technology adoption.
Farm Income (> 350 USD $)	21	12	Adopters had higher financial stability, facilitating technology adoption.

This study suggests that technology adoption enhances farm income and underscores the importance of supporting financially unstable farmers. Income improvement was considered a key variable in evaluating the farmers' well-being. To assess this, income levels were analyzed before and after technology adoption, based on the respondents' self-reported data. The results obtained indicate that the income from pepper farming increased due to reduced post-

harvest losses following the implementation of post-harvest technologies. As a result, the farmers were able to sell larger quantities of pepper and achieve higher earnings. This improvement positively impacted their livelihoods.
The results of the binary logistic regression analysis are presented in Table 2, and the tested hypotheses are outlined below.

Hypotheses
H0 – Internet accessibility, credit accessibility, machinery costs, farm income, training participation, farming experience, and distance to the market center have no effect on technology adoption.
H1 – Internet accessibility influences technology adoption.
H2 – Credit accessibility influences technology adoption.
H3 – Machinery costs influence technology adoption.
H4 - Farm income influences technology adoption.
H5 - Participation in training influences technology adoption.
H6 - Farming experience influences technology adoption.
H7- Distance to the market center influences technology adoption.

Table 2. Logistic regression model results

	B	S. E	Wald	df	Sig	Exp(B)
(Intercept)	0.910	1.9940	0.208	1	0.648	
Institutional factors						
Internet accessibility	4.275	1.822	5.508	1	0.019	71.903
Credit accessibility	5.874	2.245	6.846	1	0.009	355.701
Training participation	-0.355	1.469	0.058	1	0.809	0.701
Economic factors						
Cost of production	0.000	0.000	5.959	1	0.015	1.000
Farm income	0.000	0.000	0.295	1	0.587	1.000
Distance to marketplace	0.112	0.056	0.122	1	0.726	1.023
Social factors						
Farm experience	0.023	0.065	0.122	1	0.726	1.023
Constant	-8.907	2.928	9.257	1	0.002	0.000

According to the binary logistic regression results (Table 2), the farm income, training participation, and farming experience are not significant at the 0.05 significance level. However, the internet accessibility ($p = 0.019$), credit accessibility ($p = 0.009$), cost of production ($p = 0.015$), and distance to the marketplace ($p = 0.045$) are statistically significant at $\alpha = 0.05$. These findings indicate that only economic and institutional factors significantly influence the farmers' adoption of new technologies. Specifically, internet accessibility, credit accessibility, cost of production, and distance to the marketplace affect the adoption of post-harvest technologies.
The corresponding model, where $\hat{P}$ is the estimated probability of being a technology adopter, is as follows:

$$\ln \frac{\hat{p}}{1-\hat{p}} = - 8.907 - 4.275\ \text{Int\_acc} - 5.874\ \text{Crdta\_acc} + 0.000\ \text{Cfp} - 0.000\ \text{Farm\_incom} + - 0.355\ \text{Training\_participation} + 0.023\ \text{Frm\_exp} + 0.112\ \text{Distc}$$

$$\text{If } Y = \ln\left(\frac{\hat{p}}{1-\hat{p}}\right) \text{ then } \hat{P} = \frac{\exp(Y)}{1+\exp(Y)}$$

$$\hat{P}(\text{no}) = 1 - \hat{P}$$

The study identified several significant factors influencing the technology adoption among pepper farmers in the Kegalle district. Internet accessibility emerged as a critical determinant, exhibiting a significant positive effect at the 5% level. The model indicated that each unit increase in internet accessibility increases the probability of technology adoption by a factor of 4.275. Furthermore, the farmers with internet access are 71.903 times more likely to adopt new technologies than those without, as they can obtain up-to-date information on post-harvest technologies. These findings align with those of Jain and Rekha (2017), who highlighted the pivotal role of information access in technology diffusion.
Credit accessibility also had a significant positive effect on technology adoption, with each unit increase in credit access raising the likelihood of adoption by a factor of 5.874. The farmers with access to credit were 355.701 times

more likely to adopt new technologies. The availability of credit enhances the farmers' financial capacity to invest in machinery, thus reducing the perceived risks associated with technological investments. This finding is consistent with the studies of Nasereldin et al. (2023) and Bokusheva et al. (2012), which emphasized the crucial role of credit in facilitating technology adoption.

The cost of production (COP) emerged as a significant factor with a positive correlation to technology adoption. The farmers perceived the investment in advanced machinery as necessary for improving productivity, despite the higher associated costs. Many adopters considered these costs an investment in long-term benefits, such as increased efficiency and productivity. This observation aligns with the findings by Challa et al. (2014) in West Wollega, where adopters demonstrated a similar willingness to invest more in technology for future gains.

Distance to market centers also positively influenced technology adoption, with a unit increase in distance raising the log odds of adoption by 0.112. The farmers processing larger quantities of pepper using advanced technologies prioritized selling their products in distant markets where they could secure higher prices. The mean distance to the market was 11 km, reflecting a preference for profitability over proximity. This trend is consistent with the findings by Kassem et al. (2021) and Sok (2021), who observed similar relationships between market distance and technology adoption in Kenya.

Farming experience and farm income had positive but statistically insignificant impacts on technology adoption. Variability in income due to seasonal price fluctuations likely made this factor less influential, while farming experience, although contributing marginally, was not a decisive factor compared to COP and market distance.

Overall, the study underscores the importance of Internet and credit accessibility, cost considerations, and market dynamics in influencing the technology adoption among pepper farmers. These factors collectively enhance the ability and willingness of farmers to adopt modern post-harvest technologies, ultimately improving pepper quality and farmers' livelihoods.

Impact of information-seeking behavior on technology adoption

To assess the impact of farmers' information-seeking behavior on technology adoption, a binary logistic regression model was employed. The omnibus test of model coefficients yielded a p-value of 0.000, which is below the 0.05 significance threshold, indicating that the model provides a significantly better fit than the null model. The model demonstrated an overall classification accuracy of 71%, reflecting the proportion of cases correctly predicted regarding technology adoption. This result highlights the model's ability to predict the observed outcomes effectively.

Model test results

The results of the logistic regression analysis for farmers' information-seeking behaviors are presented in Table 2. The hypotheses tested in the study are outlined below.

Hypotheses

H0 – No significant relationship exists between the technology adoption and knowledge obtained from extension officers, participation in group discussions, attendance in training classes, or internet usage.

H1 - Technology adoption is significantly associated with the knowledge obtained from extension officers.

H2 - Technology adoption is significantly associated with the participation in group discussions.

H3 - Technology adoption is significantly associated with the attendance in training classes.

H4 - Technology adoption is significantly associated with the internet usage.

According to Table 3, the relationship between technology adoption and knowledge obtained from extension officers ($p = 0.077$) is significant at the 0.1 level, whereas the relationship between technology adoption and internet usage ($p < 0.001$) is significant at the 0.05 level. Therefore, the null hypothesis is rejected for these two factors, indicating that both the knowledge from extension officers and internet usage significantly influence the farmers' information-seeking behavior regarding the post-harvest processing of pepper and technology adoption.

Table 3. Model test results of the logistic regression analysis for information-seeking behavior

	B	S. E	Wald	df	Sig	Exp (B)
Knowledge from extension officers	0.368	0.208	3.135	1	0.077	1.445
Participation in group discussions	-0.161	0.228	0.499	1	0.480	0.851
Attendance in training classes	-0.054	0.230	0.055	1	0.814	0.947
Internet usage	0.522	0.143	13.289	1	0.000	1.685
Constant	-2.503	1.304	3.684	1	0.055	0.082

The coefficient for knowledge obtained from extension officers was positive and statistically significant. A one-unit increase in engagement with the extension officers is associated with a 0.368 increase in the probability of technology adoption. The odds of adopting the technology among the farmers who frequently contact extension officers are 1.44 times higher than those who do not seek information from extension officers. This finding suggests that farmers who adopt technology are more likely to engage with extension officers and follow their guidance.
The coefficient for knowledge acquisition through internet searches was positive and statistically significant. A one-unit increase in the internet usage for information-seeking is associated with a 0.522 increase in the probability of technology adoption. The odds of adopting the technology among the farmers who search the internet for information are 1.685 times higher than those who do not. Internet accessibility enables farmers to stay updated on modern technologies, making it a significant factor in technology adoption. Therefore, internet usage plays a crucial role in the farmers' adoption of new technologies.

Comparison of satisfaction levels with extension services for new processing technologies between adopters and non-adopters

According to the results, 40.3% of the respondents were highly satisfied with the extension services provided by extension officers. Similarly, they expressed strong satisfaction with the training sessions conducted by the DEA and Oxford Committee for Famine Relief (OXFAM) organizations. In contrast, only 6.383% of the respondents reported high satisfaction with the group discussions, representing the lowest level of satisfaction. The highest satisfaction rate was observed for the informational leaflets (44.8%), whereas 31.91% of the respondents were satisfied with both the extension services and group discussions, the lowest satisfaction level among the evaluated aspects. A neutral satisfaction level was reported by 19.15% of the respondents for the group discussions, training classes, and seminars, whereas the lowest neutral satisfaction rate was observed for the extension officers (8.511%). The highest dissatisfaction rate was recorded for the group discussions (42.55%), indicating a need for improvement in this area.
The technology non-adopters also reported high satisfaction with the extension officers (28.30%), while the highest satisfaction level was observed for the informational leaflets (45.28%). Neutral satisfaction was also highest for the leaflets (24.53%), whereas the extension officers received the lowest neutral satisfaction (7.547%). The highest dissatisfaction was recorded for the group discussions (39.62%), while the leaflets had the lowest dissatisfaction rate (13.24%). These findings indicate that the leaflets provided by the department on processing technologies are at a satisfactory level. Moreover, strong dissatisfaction was notably high for group discussions (7.547%).
Based on these findings, the researcher must determine whether a significant difference exists in satisfaction levels with the extension services between the technology adopters and non-adopters using a parametric test. The hypotheses and results of the test are presented below. Table 4, 5 and 6 display the results of the Mann-Whitney U test.

Hypotheses

H0 – There is no significant difference in satisfaction levels between the technology adopters and non-adopters.
H1 - There is a significant difference in satisfaction levels between the technology adopters and non-adopters.

According to Table 4, the results indicate that only the training classes ($p = 0.026$) were significant at the 0.05 significance level. Therefore, the null hypothesis can be rejected, indicating a significant difference between the two groups in satisfaction with the training classes. All other variables were not significant, and thus, the null hypothesis cannot be rejected, suggesting no significant difference in satisfaction with other extension services. Satisfaction levels regarding the extension officers, group discussions, leaflets, and seminars were similar between the two groups. These findings demonstrate that satisfaction with the training classes differed between the adopters and non-adopters, with a higher percentage of the adopters (21.26%) reporting strong satisfaction compared to the non-adopters (11.54%).

Table 4. Mann-Whitney U test results of satisfaction levels with extension services

	Extension officers	**Group discussions**	**Leaflets**	**Training classes**	**Seminars**
Mann – Whitney U	1,127.500	1,184.000	1,192.000	916.000	1,040.000
Wilcoxon W	2,558.500	2,615.000	2,623.000	2,294.000	2,471.000
Z	-0.854	-0.449	-0.391	-2.227	-1.484
Asymp. Sig.(2 – tailed)	0.393	0.653	0.695	0.026	0.138

According to Table 5, the mean rank value was higher among the technology adopters (56.51%), indicating greater satisfaction with the training classes compared to the non-adopters. This finding suggests that the adopters were more satisfied with the training sessions. Among the adopters, five individuals held diplomas, seven had a university education, and one had postgraduate education. Compared to the non-adopters, the adopters had a higher level of education, enabling them to derive greater benefits from the training sessions, which likely contributed to their higher satisfaction. Moreover, the majority of technology adopters in this sample (32%) were fully engaged in farming activities. Their primary objective was to enhance production, efficiency, and product quality to a greater extent than the non-adopters. Consequently, they were more motivated to participate in the training sessions on technology usage and expand their knowledge compared to the non-adopters.

Table 5. Mann-Whitney U test results for the mean ranks

	Technology adoption	N	Mean rank	Sum of the ranks
Training classes	No	53	44.12	2,294.00
	Yes	47	56.51	2,656.00
	Total	100		

Identification of the impact of technology adoption on the adopters and non-adopters

To assess the impact of technology adoption on the adopters and non-adopters, the Mann-Whitney U test, a non-parametric statistical test, was employed. The hypotheses tested are as follows, and the corresponding results are presented in Table 6.

Hypotheses

H0 – There is no difference in the income level or consumption expenditure between the adopters and non-adopters.
H1 - There is a difference in the income level between the adopters and non-adopters.
H2 - There is a difference in the consumption expenditure between the adopters and non-adopters.

Table 6. Mann-Whitney U Test Results for differences in income and consumption expenditure

Independent variable		Mean rank	Asymptotic sig	Tested hypothesis result
Farm income	Adopters	61.38	0.000	Reject the null
	Non-adopters	40.85		
Consumption expenditure	Adopters	65.84	0.000	Reject the null
	Non-adopters	36.90		

According to the results, both the income level and consumption expenditure were statistically significant, allowing for the rejection of the null hypothesis. Therefore, a significant difference in the income and consumption expenditure was observed between the two groups. The mean rank values for the income level (61.38) and consumption expenditure (65.84) were higher among the adopters then those among the non-adopters.

CONCLUSION

The findings of this study highlight the transformative impact of post-harvest technology adoption among the smallholder pepper farmers in the Kegalle district of Sri Lanka. By examining the determinants and outcomes of technology adoption, the research provides significant insights essential for agricultural development and policy formulation. A key finding is the substantial influence of information sources in shaping the farmers' awareness and adoption of post-harvest technologies. The Department of Export Agriculture (DEA), extension officers, and the internet were identified as the primary channels through which the farmers acquire knowledge about these innovations, emphasizing the importance of effective information dissemination strategies in promoting technology uptake. Despite initial apprehensions, a significant proportion of the non-adopters expressed a preference for post-harvest technologies, with dryers being the most favored option. This finding indicates a growing recognition of the benefits of modernizing production processes and highlights the necessity of addressing adoption barriers such as access to credit and market proximity, which emerged as significant determinants. Credit accessibility played a crucial role in facilitating technology adoption, as the farmers with better access to financial resources exhibited higher adoption rates. This underscores the need for targeted financial support mechanisms tailored to smallholder farmers, particularly in resource-constrained settings. Although concerns about higher production costs were identified, the farmers demonstrated a willingness to invest in new technologies, driven by the anticipation of long-

term benefits. This suggests that while cost considerations are important, they do not constitute insurmountable barriers to adoption, particularly when weighed against potential gains in productivity and profitability. The study also underscores the vital role of extension services and internet resources in influencing the farmers' adoption decisions. Training sessions, in particular, were identified as significant drivers of satisfaction among the adopters, facilitating the practical application of learned techniques. These findings highlight the importance of investing in extension programs and capacity-building initiatives to support technology adoption and knowledge transfer within agricultural communities. Furthermore, the study demonstrates the positive impact of technology adoption on the farmers' livelihoods, including increased income, higher consumption expenditures, and improved food security. The respondents reported a substantial increase in income following the adoption of post-harvest technologies, primarily due to a reduction in post-harvest losses of pepper, which positively influenced their overall well-being. These outcomes underscore the transformative potential of post-harvest technologies in enhancing the farmers' livelihoods and contributing to poverty alleviation efforts.

Although this study provides valuable insights, certain limitations highlight the need for further research. The study primarily focuses on a specific district, which restricts the generalizability of the findings to other regions with different socioeconomic and environmental conditions. To enhance the applicability of the results, future studies should expand their scope to encompass a broader range of geographic areas. As the use of cross-sectional data may not fully capture changes in technology adoption over time, longitudinal studies could provide a deeper understanding of the long-term effects of post-harvest technologies on the farmers' livelihoods. Moreover, given the potential challenges women farmers face in accessing credit, training, and technology, future research should explore gender-specific barriers to adoption. An in-depth examination of the environmental implications of technology adoption, such as energy efficiency and the carbon footprint of post-harvest technologies, would provide a more comprehensive assessment of its benefits and potential drawbacks. These avenues for further investigation would strengthen the robustness of the findings and offer valuable insights for practitioners and policymakers. To enhance technology adoption, policymakers and practitioners should prioritize improving information dissemination through extension services and digital platforms, facilitating farmers' access to credit, and expanding training programs to ensure effective knowledge transfer. Addressing barriers such as market proximity and integrating gender-sensitive and environmentally sustainable approaches can further promote the adoption of post-harvest technologies. These efforts will contribute to improved farmer livelihoods, increased productivity, and broader poverty alleviation.

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