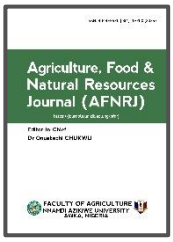
Agr. Foo. Nat. Res. J. Volume 4, Issue 1, Page 185 - 191

e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal

The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj



Original Article

Factors influencing adoption of improved postharvest storage technologies among grain traders in Ilorin metropolis, Kwara State, Nigeria

OPEN ACCESS

Olaoluwa Babatunde OGUNREMI[1]*, Olayinka Jelili YUSUF[2] & Felicia Motunrayo OLOOTO[2]

[1]*Research Outreach Department, Nigerian Stored Products Research Institute, P.M.B 1489, Ilorin, Kwara State, Nigeria*
[2]*Department of Agricultural Economics and Extension Services, Kwara State University, Malete, Kwara State, Nigeria.*

DOI: https://www.doi.org/10.5281/zenodo.15113957

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *January 11, 2025*
Accepted: *February 27, 2025*
Available online: *March 31, 2025*

Peer-review: *Externally peer-reviewed*

Copyright: © 2025 Author(s)
This is an open access article licensed under Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/) which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Conflict of Interest: *The authors have no conflicts of interest to declare*

Financial Disclosure: *The authors declared that this study has received no financial support.*

ABSTRACT

Postharvest grain losses, particularly for staple crops, are a significant challenge to food security in Nigeria, with losses estimated between 20% and 35%. This study examined the factors influencing the adoption of improved postharvest storage technologies (IPSTs) among grain traders in Ilorin metropolis, Kwara State, Nigeria. A two-stage sampling technique was employed to select 229 respondents from four major grain markets in Ilorin, Nigeria. Data were collected through a structured interview schedule and questionnaire as the instrument. Analysis involved both descriptive and inferential statistics, with binomial logistic regression identifying key factors influencing technology adoption. The results showed that grain traders had an average age of 45, with men (77.3%). The majority of the respondents were married (81.8%) and had primary education (51.8%). They had an average of 13 years in the grain trade and earned an average weekly income of ₦250,000 ($166). The majority (98.2%) were aware of improved postharvest storage technologies, with the usage of Purdue Improved Crop Storage (PICS) bags (51.5%) ranking first. Grain-based associations were the main source of information on awareness of IPSTs among respondents. The perceived benefits of IPSTs, starting with the most important, included improved grain quality, extended shelf life, and reduced pest infestation with a mean score of 4.39, 4.13, and 4.08, respectively. Binomial logistic regression indicated that education, association membership, access to credit, and income significantly influenced the usage of IPST among grain traders in the study area. The study recommends improving access to credit, enhancing training, and strengthening trade associations to promote IPST usage and reduce postharvest losses.

KEYWORDS: *Adoption, Cereals, Food security, Postharvest, Sustainability*

INTRODUCTION

Grain cereals such as maize, sorghum, wheat, and millet are critical to food security for many households and form the cornerstone of global food systems (Amit *et al.*, 2024). In Sub-Saharan Africa (SSA), these crops are cultivated on approximately 200 million hectares, supporting diverse agricultural practices and catering to a wide array of socio-economic needs and dietary preferences (Erenstein *et al.*, 2022). Grain crops are crucial for ensuring food security, driving economic stability, and providing employment opportunities in both rural and urban areas (Ittersum *et al.*, 2013; Fisher *et al.*, 2017). As one of the leading grain producers in Africa, Nigeria consistently records annual outputs exceeding 20 million metric tons (Epule *et al.*, 2022). Despite these achievements in grain production, significant challenges persist, particularly in the

*Corresponding author: olaoluwaoguns@gmail.com

form of postharvest losses which occur at various stages, including harvesting, drying, threshing, transportation, and storage, posing a critical challenge to grain traders who are vital players in the supply chain. These losses, estimated at 20% to 40% of total grain production, significantly reduce the volume and quality of grains available to markets and households (Aphlis, 2013; FAO, 2021). Postharvest losses create considerable economic setbacks, leading to substantial revenue loss for the traders (Ogundele, 2022). Minimizing these losses requires effective storage practices to preserve grain quality over time. Improved postharvest storage technologies (IPSTs), such as hermetic storage bags and metal silos, have proven effective in mitigating pest infestations, moisture infiltration, and fungal growth (Foster *et al.*, 2024; Yewle *et al.*, 2024). These technologies enable traders to secure better prices, stabilize food supplies, and sustain their businesses economically. However, despite their demonstrated effectiveness, the use of IPSTs remains limited among Nigerian grain traders. Traditional storage methods such as mud silos, woven sacks, and open-air storage are still prevalent among traders. These methods, while affordable and widely accessible, inadequately protect grains from pests, moisture, and other factors that lead to deterioration (Affognon *et al.*, 2015). Despite government efforts, including the establishment of research institutes, the use of modern storage technologies has been slow. This highlights the need to better understand the factors that influence the use of IPSTs among grain traders.

This study investigates the factors affecting the adoption of improved postharvest storage technologies among grain traders in Ilorin metropolis, Kwara State. Specifically, the study examines the socio-economic characteristics of grain traders, their level of awareness of IPSTs, and their perceptions of the potential benefits of using these technologies. Additionally, the study explores the extent of IPST usage among traders and identifies key socio-economic factors influencing their adoption. By addressing these objectives, the study aims to provide insights into the barriers and enablers of IPST usage, contributing to the development of targeted interventions that can enhance technology uptake. Such interventions are critical for reducing postharvest losses, improving the profitability of grain traders, and strengthening food security in Nigeria.

MATERIAL AND METHODS

Study Area

This study was conducted in Ilorin, the capital city of Kwara State, Nigeria. The city is located in Nigeria's North-Central region which lies between latitudes 8°24′ and 8°36′ North and longitudes 4°10′ and 4°36′ East, strategically positioned as a gateway between northern and southern Nigeria. The city is situated within three Local Government Areas (LGAs): Ilorin East, Ilorin South, and Ilorin West, making it a central administrative and commercial hub. Kwara State itself is made up of sixteen (16) LGAs, including Asa, Baruten, Edu, Ekiti, Ifelodun, Ilorin East, Ilorin South, Ilorin West, Irepodun, Isin, Kaiama, Moro, Offa, Oke-Ero, Oyun, and Patigi. Agriculture is the backbone of the state's economy, with key cash crops such as cocoa, beniseed, palm produce, maize, sorghum, millet, onions, and cowpea being vital to both subsistence and commercial farming. These crops, particularly grains, form the core of trade activities in major markets within the study area, providing significant opportunities for grain traders to thrive.

Sampling Techniques and Sample Size

A two-stage sampling procedure was employed to select respondents for the study. In the first stage, four major grain markets; Mandate, Ago, Ipata, and Oja-Titunwere purposively selected based on their high level of grain trading activities. Using the Taro Yamane formula with a precision level of 0.05, the sample size was determined to be 229 respondents from a total population of 538 registered grain traders across these markets. In the second stage, a proportionate random sampling technique was applied to select 42.5% of traders from each market, ensuring adequate representation of the calculated sample size.

Method of Data Collection

Data were collected using a structured interview schedule, designed to gather detailed information from the respondents. Data were primarily collected using a structured questionnaire aligned with the study's objectives and relevant literature. The questionnaire was employed to gather appropriate information and was pre-tested before being administered to ensure clarity and reliability. The data collection instrument underwent content validation through consultations with experts in the field to ensure its relevance and accuracy.

Analytical Techniques

The data analysis employed both descriptive and inferential statistical tools. Descriptive statistics, including frequency, percentage, mean, standard deviation and likert-type scale analysis, were used to summarize and present the data. For inferential statistics, binomial logistic regression was utilized to examine relationships between key variables and determine the factors influencing the use of improved postharvest storage technologies. Binomial logistic regression is an appropriate statistical tool for examining the relationship between a categorical dependent variable and multiple independent variables, especially when the dependent variable has two possible outcomes (e.g., usage vs. non-usage of improved postharvest storage technologies). In this study, the dependent variable represents the usage (or non-usage) of improved storage technologies, which is a binary outcome. The choice of binomial logistic regression is justified because it allows for the analysis of how various socio-economic factors influence the likelihood of using these technologies.

The regression model is mathematically expressed as:

$$Y_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \ldots \beta_8 X_8 + U_i \quad (1)$$

Where: Y = Usage of Improved Postharvest Storage Technologies (Used = 1, Otherwise = 0), β_0 = Constant (intercept);X_1 = Age (years), X_2 = Gender (Male = 1, Otherwise = 0), X_3 = Marital status (Married = 1, Otherwise = 0), X_4 = Level of educational (Formal education = 1, Otherwise = 0), X_5 = Membership of association (Yes = 1, No = 0), X_6 = Access to credit facilities (Yes = 1, Otherwise = 0), X_7 = Years of experience (years), X_8 = Average weekly income (₦), X_1-X_8= independent variables, βi (β_1 – β_8) = vector of the estimated parameters or unknown coefficients, U_i = Error term

RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of the Respondents

Results in Table 1 shows that most of the farmers were middle aged (Mean age of 45 years), ranging between 41 and 50 years of age. This implied that most of the respondents were in their active years and as such could participate effectively in grain trading activities. Most of the respondents were (77.3%) male, while 22.7% were female. This implies that there is dominance of male gender in grain trading in the study area. Majority of the respondents (81.8%), while 7.1% were single, 5.9% widowed, 4.1% separated, and 1.2% divorced. The high percentage of married participants is indicative of the role grain trading plays as a stable source of income to support family needs, consistent with the findings of Park (2006), who noted that grain trading provides a reliable income stream, essential for meeting family needs, especially in rural areas where alternative employment opportunities may be limited. Result of data analysis also revealed that over half (51.8%) had only primary education, while a mere 5.3% had reached tertiary education. About (50.2%) of the traders have been in grain trading business for more than 13 years. Household income data indicated that the average monthly income was approximately ₦250,000, reflecting a moderate level of economic engagement in grain trading. This income level is critical for sustaining the average household size of 5 persons reported among respondents, highlighting the role of grain trading in supporting livelihoods. Larger households often require more food security, leading them to store more grain as a precautionary measure against price volatility and yield uncertainty (Park, 2006). Furthermore, access to credit was reported by 74.1% of the traders, with cooperatives being the predominant source (42.9%), while only 3.5% accessed bank loans. This reveals the pivotal role of cooperatives in providing financial resources, a finding supported by Miroshnichenko (2020), who reported that cooperatives are vital in bridging the financial gap in agribusiness, especially in rural areas.

Awareness on Improved Grain Storage Technologies

Results from the study, as presented in Table 2, indicate that an overwhelming majority (98.2%) of grain traders in the study area are aware of improved grain storage technologies. This high level of awareness suggests that information on modern storage methods has been widely disseminated, possibly due to the traders' membership in grain-based associations.

Table 1: Socio-economic Characteristics of Respondents

Socio-economic characteristics	Frequency (n=229)	Percentage (%)
Sex		
Male	177	77.3
Female	52	22.7
Age (years)		
21-30	4	1.7
31-40	55	24.0
41-50	120	52.4
51-60	35	15.3
61-70	15	6.6
Mean±Standard Deviation		**45±8.52**
Marital Status		
Single	16	7.1
Married	187	81.8
Divorced	3	1.2
Separated	9	4.1
Widowed	14	5.9
Household Size		
1-3	70	30.6
4-6	125	54.6
Mean±Standard Deviation		**5±1.97**
7 and above	34	14.8
Level of Education		
No formal education	31	13.5
Primary	119	51.8
Secondary	67	29.4
Tertiary	12	5.3
Weekly Income (₦)		
≤100,000	80	34.9
101,000 - 200,000	40	17.5
201,000 - 300,000	50	21.8
301,000 - 400,000	20	8.7
401,000 -500,000	15	6.5
501,000 and above	24	10.6
Mean±Standard Deviation		**250,000± 165,789.14**
Trading Experience (years)		
≤ 10 years	80	34.9
11-20 years	115	50.2
21-30 years	25	10.9
Mean±Standard Deviation		**13±7.68**
31 years and above	9	3.9
Access to Credit		
Yes	170	74.1
No	59	25.9
Sources of Credit		
Cooperative	73	42.9
Money lender	47	27.6
Bank	6	3.5
Friend/Family	44	26

Among the specific technologies, PICS bags had the highest awareness level (51.5%), followed by Zero Fly bags (29.7%), hermetic steel drums (13.6%), and silos (5.2%). The dominance of awareness regarding PICS bags reflects the efforts made in promoting this technology, which has proven to be effective in reducing postharvest losses. The findings of this study contrast with those of Moussa *et al.* (2011), who reported generally low awareness among Nigerian traders, particularly regarding hermetic storage bags and metal silos. Similarly, Aidoo *et al.* (2012) highlighted that awareness levels were strongly linked to access to extension services and participation in agricultural programs, suggesting that direct exposure to such initiatives enhances traders' knowledge of modern storage technologies.

Regarding the sources of information, 56.5% of respondents received information about these improved storage technologies through their grain-based associations, while 19.4% received information from fellow traders, 15.3% from ADP/Extension agents, 5.3% from radio, 2.9% from relatives and friends, and 0.6% from television. This reliance on associations aligns with the findings of Ajuwon & Odeku (2012), as well as Mugwisi & Mostert (2012), who identified face-to-face communication through family, friends, and neighbors as one of the most effective means of disseminating agricultural information. The dominance of associations as a primary information source further emphasizes the significance of peer networks and grassroots communication in promoting technology adoption in the study area.

Perceived Benefits of Using Improved Storage Technologies

Results presented in Table 3 indicate that the most significant perceived benefit of using improved storage technologies is the ability to maintain grain quality over time, which ranked as the highest advantage. This finding underscores the importance of these technologies in preserving both the integrity and market value of stored grains, ensuring that traders can sell their produce at optimal prices. The ability to retain grain quality is particularly crucial in minimizing postharvest losses and preventing deterioration during storage. Studies have shown that improved storage technologies, such as PICS bags and hermetic drums, significantly extend the storage duration of grains while maintaining their quality. For instance, Omotilewa *et al.* (2019) found that the use of hermetic storage bags in Uganda improved maize storage capacity and prolonged shelf life, thereby enhancing food security during lean seasons. Similarly, Tesfaye & Tirivayi (2016) reported that improved storage innovations in Ethiopia positively impacted food security and household welfare, further emphasizing the long-term benefits of adopting modern storage methods.

Beyond quality retention, traders also recognized other critical benefits. The extended shelf life of stored grains ranked second, followed by a reduction in pest infestation, an increased potential for profit, and a reduction in financial losses, ranking third, fourth, and fifth, respectively. These findings align with existing research, which highlights how improved storage technologies not only preserve grain quality but also contribute to greater economic stability for traders by reducing losses and maximizing returns.

Table 2: Awareness of Improved Technology and Sources of Information

	Frequency	Percentage (%)
Awareness on Improved Technology		
Yes	226	98.7
No	3	1.3
Total	229	100.0
Technology Aware of		
PICS bags	118	51.5
Zero fly bags	68	29.7
Silo	12	5.2
Hermetic Steel drum	31	13.6
Total	*329	100.0
Sources of Information		
Association	129	56.5
Fellow Trader	53	19.4
ADP/Extension agents	35	15.3
Radio	12	5.3
Relatives and Friends	6	2.9
Television	1	0.6
Total	*236	100.0

** = Multiple responses*

Table 3: Perception Statement on the Benefit associated with the usage of Improved Technologies

Storage Facilities	Strongly Disagree (%)	Disagree (%)	Not Sure (%)	Agree (%)	Strongly Agree (%)	Mean Score	Rank
Quality did not diminish	0 (0.0)	0 (0.0)	22 (9.6)	95 (41.5)	112 (48.9)	4.39	1st
Extended shelf life	0 (0.0)	0 (0.0)	39 (17.0)	121 (52.9)	69 (30.1)	4.13	2nd
Pest infestation reduced	0 (0.0)	0 (0.0)	52 (22.7)	105 (45.9)	72 (31.4)	4.08	3rd
Profit increased	91 (39.7)	10 (4.4)	23 (10.0)	105 (46.0)	0 (0.0)	2.64	4th
Financial loss reduced	91 (39.7)	0 (0.0)	56 (24.5)	82 (35.8)	0 (0.0)	2.57	5th

NB: Strongly agree=5, Agree=4, Not sure=3, Disagree=2, Strongly disagree=1

Usage of Improved Postharvest Storage Technology

Results from the study indicate that PICS bags are the most frequently used storage technology, with a high mean score of 4.53. A significant majority (60.1%) of respondents reported always using PICS bags, while an additional 23.7% stated that they use them occasionally. Only a small proportion (4.4%) indicated that they never use this technology. The widespread adoption of PICS bags aligns with broader trends observed in recent years. According to Baributsa and Ignacio (2020), the use of hermetic bags for grain storage has significantly increased over the past decade, driven by the development and promotion of Purdue Improved Crop Storage (PICS) bags. This increase highlights their effectiveness in preventing grain deterioration and postharvest losses. Chemical preservatives ranked second in usage, with a mean score of 4.45. Over half of the respondents (52.4%) reported always using chemicals for grain storage, while 25.7% used them occasionally. However, 6.5% of respondents indicated that they never use chemicals. While chemicals remain a widely used preservation method, their application poses potential risks, including environmental contamination, health hazards, and the development of pest resistance. Kumar & Kalita (2017) emphasized that proper knowledge of chemical usage is essential to minimize these risks and ensure safe grain storage.

Zero Fly bags ranked third, with a mean score of 4.14. Although 52.8% of respondents reported using these bags occasionally, only 17.2% indicated that they always use them. Hermetic drums had the lowest mean score (4.00), reflecting relatively limited adoption. A significant proportion of traders (30.5%) reported never using hermetic drums, while 37.6% used them only rarely. The findings reveal a gradual shift from traditional storage methods to modern technologies among grain traders. While PICS bags are widely embraced, other improved technologies, such as chemicals, Zero Fly bags, and hermetic drums, are less commonly used, likely due to cost, accessibility, and technical know-how. Consistent awareness campaigns, coupled with enhanced support for access and proper usage of these technologies, could significantly improve grain preservation and reduce postharvest losses in the long run.

Table 4: Level of use of Improved Postharvest Storage Technology

Storage Technology	Never (%)	Rarely (%)	Sometimes (%)	Always (%)	Mean	Rank
PICS Bags	10 (4.4%)	27 (11.8%)	55 (23.7%)	137 (60.1%)	4.53	1st
Chemicals	15 (6.5%)	35 (15.3%)	59 (25.7%)	120 (52.4%)	4.45	2nd
Zero Fly Bags	48 (21.0%)	18 (7.7%)	121 (52.8%)	39 (17.2%)	4.14	3rd
Hermetic Drums	70 (30.5%)	86 (37.6%)	51 (22.2%)	22 (9.6%)	4.00	4th

Socio-economic Factors Influencing the use of Improved Grain Storage

The results of the binomial logistic regression revealed that several socio-economic factors significantly influenced the usage of improved postharvest storage technologies (IPSTs). Key predictors included average weekly income ($B = 0.080$, $p < 0.05$), education level ($B = 0.090$, $p < 0.05$), membership in associations ($B = 0.150$, $p < 0.05$), and access to credit facilities ($B = 0.130$, $p < 0.05$). These factors had positive coefficients, indicating that higher income, better education, active membership in associations, and access to credit substantially increased the likelihood of adopting improved storage practices. Education emerged as a critical determinant, as traders with higher educational attainment were more likely to adopt IPSTs due to their ability to understand and appreciate the benefits of these technologies. This finding aligns with earlier studies by Adefalu *et al.* (2018), which underscored the positive impact of education on technology adoption. As educational attainment increases, so does the probability of using improved storage methods, highlighting the need for educational programs to promote the use of such innovations. Membership in associations also played a pivotal role by providing traders with access to shared resources, information, and financial support, thereby reducing barriers to IPST usage. This finding corroborates the work of Onumah *et al.* (2021), who emphasized the role of group participation in enhancing access to market knowledge and innovation. The statistical significance of this variable suggests that associations facilitate the adoption of IPSTs through mechanisms such as financial support, collective bargaining power, and peer influence. While all respondents were part of associations, the networks' impact in overcoming individual barriers to technology use was particularly evident.

Similarly, traders with higher weekly incomes were better equipped to afford the costs associated with adopting improved technologies. This observation is consistent with the findings of Budu (2019), which identified income and financial incentives as a key factor in technology adoption. An increase in income significantly enhances the likelihood of using improved storage solutions, underscoring the importance of financial capacity in decision-making. Lastly, access to credit facilities proved essential for enabling traders to make the necessary financial investments in advanced storage methods. This finding aligns with research by Mohamed (2018), which highlighted the critical role of credit in facilitating technology adoption. Greater access to credit significantly boosts traders' ability to invest in IPSTs, emphasizing the importance of robust financial systems in promoting agricultural innovations.

Table 5: Factors Influencing the use of Improved Grain Storage among Traders

Variables	Coefficient (B)	Standard Error	t-Value	p-Value	Significance
(Constant)	0.450	0.230	1.957	0.052	-
Years of Experience	0.015	0.012	1.250	0.213	Not Significant
Average Weekly Income	0.080	0.020	4.000	0.000*	Significant
Age	-0.005	0.014	-0.357	0.722	Not Significant
Gender	-0.030	0.040	-0.750	0.454	Not Significant
Marital Status	0.020	0.035	0.571	0.570	Not Significant
Level of Education	0.090	0.025	3.600	0.001*	Significant
Member of Association	0.150	0.040	3.750	0.000*	Significant
Access to Credit Facilities	0.130	0.045	2.889	0.004*	Significant

*Note: * implies statistical significance at $p < 0.05$*

CONCLUSION AND RECOMMENDATION

The study concluded that most of the respondents are aware of IPSTs although their usage varies with PICs bag ranking first. The findings further highlighted the significant role of socio-economic factors, including income, education, association membership, and access to credit, in influencing the use of IPSTs. Conversely, demographic factors such as age, gender, marital status, and years of experience were found to have little or no impact. This revealed the need for targeted interventions to address critical socio-economic barriers to use of IPSTs.

To enhance the adoption of improved postharvest storage technologies, several strategic measures should be implemented. First, government and financial institutions should provide low-interest loans or subsidies to improve traders' access to affordable credit for acquiring storage technologies. Additionally, agricultural extension services, NGOs, and trader associations should intensify training programs, particularly targeting traders who still rely on traditional storage methods. Furthermore, development agencies and government bodies should collaborate with trader associations to organize workshops and seminars, creating platforms for knowledge-sharing and increasing awareness of modern storage techniques. Public-private partnerships should also play a role in making storage technologies more affordable by subsidizing essential solutions like hermetic drums. Lastly, research institutions and industry stakeholders should focus on developing cost-effective and scalable storage innovations tailored to the needs of small-scale grain traders, ensuring that technology adoption is both practical and sustainable.

Acknowledgement

The authors sincerely appreciate the contributions of all individuals and institutions that supported this study. Gratitude is also extended to the grain traders in Kwara State for their cooperation and willingness to participate in the study. Additionally, the authors acknowledge the valuable insights and feedback provided by experts who reviewed the manuscript.

Authors' Contribution

OBO conceptualized the study, developed the research design, collected and analyzed the data, and drafted the manuscript. OJY provided guidance on the study design, supervised data collection, and contributed to refining the methodology and interpretation of results. FMO reviewed the manuscript, provided critical feedback, and ensured the academic rigor of the research. All authors reviewed and approved the final version of the manuscript.

Ethical Statement

This study was conducted in accordance with ethical research guidelines. Necessary permissions were obtained, and respondents participated voluntarily after being informed of the study's purpose. Their privacy and confidentiality were strictly maintained throughout the research process.

REFERENCES

Adefalu, L. L., Olorunfemi, O. D., Aliyu, A. S., & Salman, M. T. (2018). Postharvest grain storage techniques utilized by traders in Ilorin West Local Government Area, Kwara State, Nigeria. *Bangladesh Journal of Extension Education*, 30(2), 1–9.

Affognon, H., Mutungi, C., Sanginga, P., & Borgemeister, C. (2015). Unpacking postharvest losses in Sub-Saharan Africa: A meta-analysis. *World Development*, 66, 49–68. https://doi.org/10.1016/j.worlddev.2014.08.002

Aidoo, R., Nimoh, F., Bakang, J. A., Ohene-Yankyera, K., Fialor, S. C., Osei Mensah, J., & Abaidoo, J. C. (2012). Estimation of margins and efficiency in the Ghanaian yam marketing chain. *Asian Journal of Agriculture and Rural Development, 2*(2), 226–234.

Ajuwon, G. A., & Odeku, E. L. (2012). *Module one: Information sources.* African Journals Online. Retrieved January 20, 2025, from http://ajol.info

Park, A. (2006). Risk and Household Grain, Management in Developing Countries, *The Economic Journal*, 116 (514): 1088–1115, https://doi.org/10.1111/j.1468-0297.2006.01124.x

Amit, A., Shahane., Y. & Singh, S. (2024). Cereal crops: A valid option for bio-fortification and development of nutrient-dense food in developing and developed countries in Asia and Africa. *Advances in Agronomy*. https://doi.org/10.1016/bs.agron.2024.02.010

Aphlis (African Postharvest Losses Information System). (2013). *Postharvest losses in sub-Saharan Africa: Data and insights*. Available at: www.aphlis.net

Baributsa, D., & Ignacio, M. C. C. (2020). Developments in the use of hermetic bags for grain storage. In *Burleigh Dodds series in agricultural science* (pp. 171–198). https://doi.org/10.19103/as.2020.0072.06

Bokar Moussa, T., Abdoulaye, T., Coulibaly, O., Baributsa, D., & Lowenberg-DeBoer, J. (2014). Adoption of on-farm hermetic storage for cowpea in West and Central Africa in 2012. *Journal of Stored Products Research*, *58*, 77–86. https://doi.org/10.1016/j.jspr.2014.02.008

Epule, T. E., Chehbouni, A., & Dhiba, D. (2022). Recent patterns in maize yield and harvest area across Africa. *Agronomy*, *12*(2), 374. https://doi.org/10.3390/agronomy12020374

Erenstein, O., Jaleta, M., Sonder, K., Mottaleb, K. A., & Prasanna, B. M. (2022). Global maize production, consumption and trade: Trends and R&D implications. *Food Security*, *14*(5), 1295–1319. https://doi.org/10.1007/s12571-022-01288-7

FAO. 2021. Evaluation of the "Food-loss reduction through improved postharvest handling and value addition of key fruits and vegetables" project in Ethiopia. Project Evaluation Series, 07/2021. Rome.

Fisher, M. H., Stein T. & Katengeza, S. P. (2017). "The adoption potential of Conservation Agriculture technologies in Malawi: A lead farmer promoter-adopter approach and assessment," CLTS Working Papers 1/17, Norwegian University of Life Sciences, Centre for Land Tenure Studies, revised 21 Oct 2019.

Ittersum, M. V., Cassman, K. G., Grassini, P., Wolf, J., Tittonell, P., & Hochman, Z. (2013). Yield gap analysis with local to global relevance—a review. *Field Crops Research*, 143, 4-17. https://doi.org/10.1016/j.fcr.2012.09.009

Joseph, B.., Jefferson, S., Edward, E., Michael, F., Bismark, T., A. & Charles, M. (2019). Explaining Technology Adoption with Financial Motivation. https://doi.org/10.1007/978-3-030-20671-0_10

Kenneth, A., Foster., Lina, M., Suarez-Guzman., Diana, C., Meza-Sepulveda., Dieudonne, B. & Carlos, A. Z. (2024). Effects of alternative hermetic bag storage on fermented and dried cocoa bean (*Theobroma cacao* L.). *Journal of Stored Products Research*, https://doi.org/10.1016/j.jspr.2024.102351

Kumar, D., & Kalita, P. (2017). Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. *Foods*, *6*(1), 8. https://doi.org/10.3390/foods6010008

Miroshnichenko, T. (2022). Increasing financial inclusion for small agribusiness as the basis for the sustainable development of rural areas. *Transbaikal State University Journal*. 28. 93-100. https://doi.org/10.21209/2227-9245-2022-28-5-93-100

Mohamed, K.S. & Temu, Andrew. (2008). Access to credit and its effect on the adoption of agricultural technologies: The case of zanzibar. *Savings and Development.* 32. 45-89.

Mugwisi, T., Ocholla, D. N., & Mostert, J. (2012). The information needs of agricultural researchers and extension workers in Zimbabwe: An overview of the findings. Retrieved January 18, 2025, from www.lis.uzulu.ac.za/research/

Nileshwari, Y., Richard, L., Stroshine., R., P., K., Ambrose., D. B. (2024). Hermetic Bags: A Short-Term Solution to Preserve High-Moisture Maize during Grain Drying. Foods, https://doi.org/10.3390/foods13050760

Ogundele, F. (2022). Postharvest Losses and Food Security in Nigeria: An Empirical Review. African Journal of Agriculture and Food Science, 5(3). https://doi.org/10.52589/ajafs-c0442z7j

Omotilewa, O. J., Ricker-Gilbert, J., & Ainembabazi, J. H. (2019). Subsidies for agricultural technology adoption: Evidence from a randomized experiment with improved grain storage bags in Uganda. *American Journal of Agricultural Economics.* https://doi.org/10.1093/ajae/aay108

Onumah, G.; Dhamankar, M.; Ponsioen, T.; Bello, M. Maize Value Chain Analysis in Nigeria; Report for the European Union, INTPA/F3. Value Chain Analysis for Development Project (VCA4D CTR 2016/375-804), 155p+ annexes; European Union: Maastricht, The Netherlands, 2021; 155p

Tesfaye, W., & Tirivayi, N. (2016). The effect of improved storage innovations on food security and welfare in Ethiopia. *MERIT Working Papers 2016-063*. United Nations University - Maastricht Economic and Social Research Institute on Innovation and Technology (MERIT).