Journal of International Agricultural and Extension Education

Volume 30
Issue 2 *30(2)*

Article 7

8-29-2023

Drivers of farmers' adoption of hermetic storage bags in Ghana

Namah Taku-Forchu
Iowa State University, namahtaku09@gmail.com

Misty D. Lambert
N C State University, mdlamber@ncsu.edu

Michael S. Retallick
Iowa State University, msr@iastate.edu

See next page for additional authors

Recommended Citation

Taku-Forchu, N., Lambert, M. D., Retallick, M. S., Ulmer, J. D., & Opit, G. P. (2023). Drivers of farmers' adoption of hermetic storage bags in Ghana. *Journal of International Agricultural and Extension Education, 30*(2), 116-136. https://doi.org/10.4148/2831-5960.1064

Drivers of farmers’ adoption of hermetic storage bags in Ghana

Abstract

Post-harvest loss is a global challenge due to its serious threat to food security. Hermetic storage bags offer one way to combat the loss of food after harvest. The rate at which farmers adopt hermetic bags largely depends upon their access to information and training about the technology. The adoption of hermetic storage bags in Dormaa, Ghana, was the focus of this quantitative cross-sectional research study. This study sought to describe maize farmers’ perceptions of the hermetic storage bags in Dormaa, Ghana, based on the perceived innovation attributes and to ascertain farmers’ stages of adoption of the hermetic storage bags using Rogers’s (2003) innovation-decision model. A multistage systematic sampling technique was used to survey 217 maize farmers in four communities where maize production was the main economic activity. Data indicated that the largest group of farmers were at the confirmation stage of Rogers’ model. The logistic regression model was used to ascertain the influence of the innovation attributes on adoption. The findings reveal that of the five innovation characteristics, relative advantage, compatibility, and complexity are the key and significant drivers of the adoption of hermetic storage bags, with relative advantage and compatibility increasing the adoption likelihood and complexity reducing it. The study, therefore, recommends that communities lagging behind others in adoption should be targeted for additional training.

Keywords

post-harvest loss, hermetic bags, extension, diffusion of innovation

Funding Source

Funding: This research was funded by United States Agency for International Development/Feed the Future (USAID/FtF), Cooperative Agreement Number AID-OAA-L-14-00002. We also thank the co-sponsor of this project David Acker, Dean of Global Engagement at Iowa State University with support from the Global Programs office. We could not have completed this project without the efforts of Alexander Danson-Anyoke and Bismark Opoku who served as enumerators and gatekeepers. We also thank all the participants in the Dormaa region who provided their data for this project.

Authors

Namah Taku-Forchu, Misty D. Lambert, Michael S. Retallick, Jonathan D. Ulmer, and George P. Opit

Drivers of farmers' adoption of hermetic storage bags in Ghana

Namah Taku-Forchu, Iowa State University
Misty D. Lambert, North Carolina State University
Michael S. Retallick, Iowa State University
Jonathan D. Ulmer, Kansas State University
George P. Opit, Oklahoma State University

Abstract

Post-harvest loss is a global challenge due to its serious threat to food security. Hermetic storage bags offer one way to combat the loss of food after harvest. The rate at which farmers adopt hermetic bags largely depends upon their access to information and training about the technology. The adoption of hermetic storage bags in Dormaa, Ghana, was the focus of this quantitative cross-sectional research study. This study sought to describe maize farmers' perceptions of the hermetic storage bags in Dormaa, Ghana, based on the perceived innovation attributes and to ascertain farmers' stages of adoption of the hermetic storage bags using Rogers's (2003) innovation-decision model*. A multistage systematic sampling technique was used to survey 217 maize farmers in four communities where maize production was the main economic activity. Data indicated that the largest group of farmers were at the confirmation stage of Rogers' model. The logistic regression model was used to ascertain the influence of the innovation attributes on adoption. The findings reveal that of the five innovation characteristics, relative advantage, compatibility, and complexity are the key and significant drivers of the adoption of hermetic storage bags, with relative advantage and compatibility increasing the adoption likelihood and complexity reducing it. The study, therefore, recommends that communities lagging behind others in adoption should be targeted for additional training.*

Keywords: post-harvest loss, hermetic bags, extension, diffusion of innovation

Funding Source/Acknowledgement: This research was funded by United States Agency for International Development/Feed the Future (USAID/FtF), Cooperative Agreement Number AID-OAA-L-14-00002. We also thank the co-sponsor of this project David Acker, Dean of Global Engagement at Iowa State University with support from the Global Programs office. We could not have completed this project without the efforts of Alexander Danson-Anyoke and Bismark Opoku who served as enumerators and gatekeepers. We also thank all the participants in the Dormaa region who provided their data for this project.

Introduction

With rising concern about feeding the growing world population, which is estimated at nine billion people by 2050, food production needs to be boosted (Godfray et al., 2010) by an estimated 60-70% above the present food production level (Silva, 2018). Governments and Non-Governmental Organizations (NGOs) are implementing policies to increase agricultural production and smallholder productivity to ensure food security (Kumar & Kalita, 2017).

Unfortunately, a significant amount of food produced does not get to the consumer. About one-third of food produced is lost or wasted, representing an equivalent of 1.3 billion tons of food yearly (Sheahan & Barrett, 2017). Halving food loss by 2030 is one of the United Nations Sustainable Development Goals. These UN goals have renewed international attention around reducing food loss to ensure minimal loss between the farm gate and consumers in the global food system (Sheahan & Barrett, 2017).

Modern storage technologies are interventions geared at reducing post-harvest loss. The use of modern storage technologies has the potential to reduce grain loss to as low as 1-2%, a significant reduction from approximately 50-60% of grain loss during storage due to technical inefficiency (Kumar & Kalita, 2017). Maize is an important grain staple for most households in Africa, including Ghana.

In Ghana, maize accounts for more than half of total grain production (Danso et al., 2017) with an annual maize production of about 1.8 million tons in 2017/2018 (Ashitey & Archibald, 2018). Increasing maize production in Ghana is not sufficient to meet growing food demands. This must be matched with decreased maize loss to ensure more maize availability. Research has found a significant amount of maize is lost during post-harvest processes in Ghana (Darfour & Rosentrater, 2016), with about 30-40% lost during storage (Opit et al., 2014). This maize storage loss is attributed to the old inefficient method of maize storage (Gockel et al., 2009; Manu et al., 2019) used by farmers, which exposes maize to insects, pest infestations, rodents, and mold and aflatoxin contamination that is harmful to human health (Danso et al., 2018; Manu et al., 2019). Due to these losses, there is a need for modern storage technologies to mitigate post-harvest maize loss, a serious threat to food security in Ghana (Danso et al., 2017; Opit et al., 2014).

Some novel storage technologies produced are metal silos, moisture meters, solar hybrid dryers, and hermetic storage bags to store and protect maize after harvest. The hermetic bags are more affordable and accessible to smallholder farmers (Baributsa & Ma Cristine, 2020) and are innovative and efficient storage technology fundamental to reducing post-harvest loss of maize (Baributsa & Ma Cristine, 2020) in contrast to the existing systems of maize storage that exposes maize to damage (Darfour & Rosentrater, 2016). The hermetic storage bags are usually multiple layers which control insects and moisture through reduced gas exchange (Baributsa & Ma Cristine, 2020; Tubbs et al., 2016). Studies reveal that hermetic bags protect maize from insect pests damage during storage for farmers in Benin (Baributsa et al., 2020), and storing maize in hermetic bags prevented aflatoxin accumulation for maize farmers in Kenya (Nganga et al., 2016). Smallholder farmers in Eastern Kenya purchased an additional one to five bags after their first experience using hermetic bags (Baributsa & Njoroge, 2020).

Despite the obvious benefits to adopters with the possibility of increased profit and the ability for farmers to store maize during peak harvest when prices plummet and sell during the off-season when prices surge, farmers have been slow to adopt the hermetic bags. Rogers' (2003) Diffusion of Innovation model elucidates this complex situation. It guides policy design and suggests interventions to increase farmers' use of hermetic bags to store maize and mitigate loss. No research publication is available to ascertain farmers' stages of adoption and farmers' perceptions of the hermetic storage bags in Ghana.

The application of the Diffusion of Innovation Theory to an innovation could serve as an orderly approach to account for factors that influence behavioral change (Warner et al., 2020). The Diffusion of Innovation theory, using the five attributes of an innovation, has been applied in assessing the adoption of water-saving technology (Lamm et al., 2017; Rodriguez et al., 2018; Warner et al., 2020). Other studies applied the Diffusion of Innovation theory to assess the adoption of Information Communication Technology (ICT) in agricultural extension (Sirajuddin, 2019; Taylor, 2015). However, no study was found which has applied the Diffusion of Innovation theory using Rogers's (2003) five innovation attributes and the innovation-decision process to identify farmers' stages of adoption and farmers' perceptions of the hermetic storage bags in Ghana which creates a research vacuum.

Purpose of the Study

This study aimed at examining maize farmers' adoption and perceptions of the hermetic storage bags.
Specifically:

1. To identify farmers' stages of adoption of the hermetic bags using Rogers's (2003) innovation-decision model.
2. To ascertain farmers' perceptions of the hermetic bags based on the innovation's attributes.

Theoretical Issues and Empirical Survey

This study is guided by Rogers' Diffusion of Innovation Theory to identify where farmers are in the adoption of the hermetic storage bags based on farmers' innovation-decision process and to ascertain farmers' perceptions of the five innovation attributes of the hermetic storage technology. According to Rogers (2003), an innovation must be widely adopted for it to be self-sustaining; in this case, the innovation is hermetic bags. This theory is widely used in research related to the adoption of agricultural technology.

Innovation-Decision Process

Rogers (2003) posits that individuals do not make decisions to adopt an innovation immediately, but through continuous processes, they make informed decisions to either adopt or reject an innovation. Individuals' final decisions could lead to adoption and making maximum use of the innovation, or rejection, where the innovation is completely ignored. Rogers (2003) conceptualized five stages (knowledge, persuasion, decision, implementation, and confirmation) of the innovation-decision process. This theory was used to determine maize farmers' current stage in the hermetic storage bag decision process. Survey questions were designed to understand farmers' level of awareness and at what stage farmers were at in the adoption process. For instance, if farmers in the study area had knowledge about the bags or they have used the bags long enough to understand they will keep using the bags. Respondents had to select only one statement that fits their position in the adoption stage with the addition of a sixth stage, "no knowledge," to capture farmers who had never heard about the hermetic bags in Dormaa, Ghana. A sixth stage, "no knowledge," was added to Rogers' innovation-decision process by Li (2004). Other studies have used the sixth stage, "no knowledge," in the innovation-decision process to include the stage at which individuals have no knowledge of the innovation (Sirajuddin, 2019; Taylor, 2015). For this study, the "no knowledge" stage captures potential adopters who have no knowledge and are not aware of the existence of the hermetic bags.

Rogers (2003) five innovation attributes (relative advantage, compatibility, complexity, trialability, observability) were used to ascertain farmers' perceptions of the hermetic bags and to provide recommendations regarding developing strategies to enhance the adoption of hermetic bags by smallholder farmers in the study area. According to Adesina and Zinnah (1993), adoption studies must consider farmers' perceptions of the specific attributes of an innovation in assessing technology adoption decisions.

Innovation Attributes

Rogers (2003) defined an innovation as anything perceived as new by the person thinking about using it. Regardless of the characteristics and nature of a person, the characteristics of an innovation affect the acceptance or rejection of an innovation (Almobarraz, 2007)**,** and farmers would adopt or reject an innovation after a series of thought processes. The attributes of an innovation help to decrease doubt about an innovation and increase adoption (Robertson et al., 2012; Rogers, 2003).

The attributes of an innovation are found to influence adoption by users (Lamm et al., 2017; Rodriguez et al., 2018). Rogers (2003) believed that peoples' perceptions of the five qualities of an innovation significantly determine the likelihood to adopt a novel technology**.**

Relative advantage, according to Rogers (2003), is when someone views an innovation, in this case, hermetic storage bags, as having an advantage over the previous ideas and practices. Relative Advantage needs to be great enough for farmers to decide to adopt. Relative Advantage can be looked at in terms of economic benefits, social status, time savings and effort reduction, and satisfaction. Lamm et al. (2017) posited that relative advantage is the perceived economic gain for adopting an innovation, and they found it to be a decisive factor influencing adoption.

Compatibility is how well-matched an innovation is with existing sociocultural values, past experiences, and the needs of the adopters (Rogers, 2003). As perceived compatibility increases, the likelihood to adopt an innovation also increases (Warner et al., 2020).

Complexity is the degree to which an innovation is perceived as relatively complex to use or understand (Rogers, 2003). The less complex it is for an individual to use and implement an innovation, the more likely they will adopt the technology (Warner et al., 2020). Sometimes adopters would reject a new technology because the procedures to implement it are complex and difficult, but when appropriate guides and instructions are provided, the innovation will easily be adopted (Warner et al., 2020).

Trialability is the degree to which an innovation can be experimented by potential adopters (Rogers, 2003). The ability to sample experimentally or try out an innovation reduces uncertainty of the innovation's complexity and provides understanding of the relative advantage (Lamm et al., 2017). According to Rogers (2003), when an innovation is trialable, uncertainty is reduced because the person considering it for adoption can learn by doing.

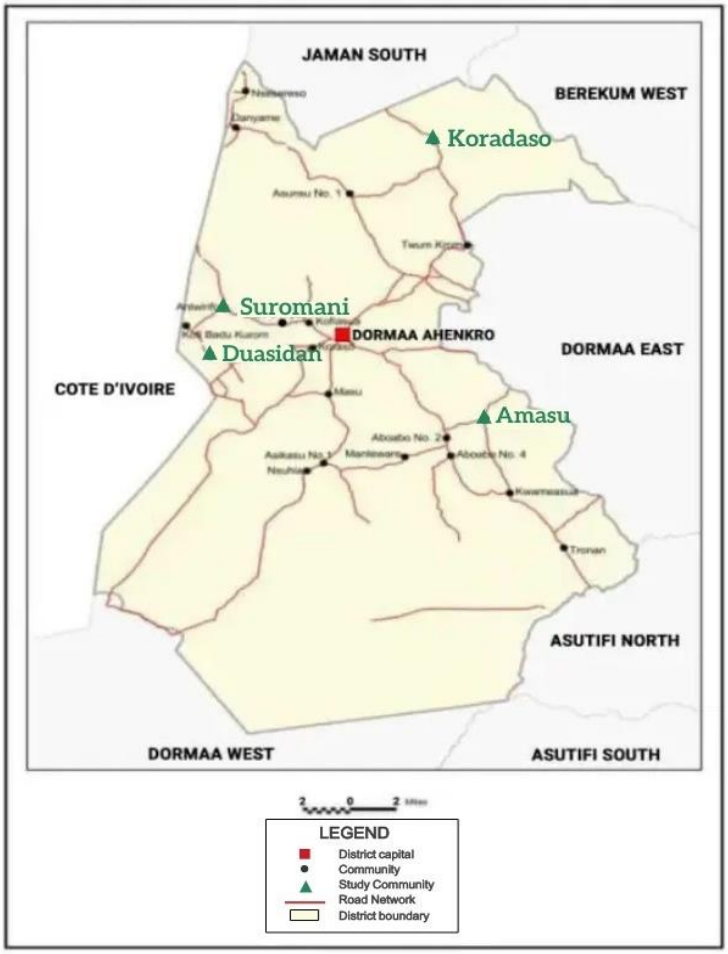
Lastly, observability is the attribute where the results and impact of an innovation are visible to users (Rogers, 2003). When adopters see the results of an innovation, it is easier for the innovation to be adopted. The impact of storing maize in hermetic storage bags can easily be seen when demonstrations are conducted with farmers by storing the same amount and quality of maize in both a hermetic storage bag and a polypropylene (PP) bag, and these bags are opened after several months for farmers to make observations. Therefore, high observability may lead to observational learning by neighbors and fellow farmers and help in the diffusion of a new technology (Lamm et al., 2017; Rodriguez et al., 2018).

Methodology

Overview of Study Area

This paper is an output of a study conducted in Dormaa, in the Bono region, Ghana which is a major maize producing region (Opit et al., 2014). The Dormaa Municipality is in the western part of the Brong-Ahafo region on longitude 30 West and latitude 70 North of Ghana. Dormaa Municipality has a total population estimated at approximately 112,111 people (Ghana Statistical Service, 2014) and a total land area of approximately 1210.8 km^2. The soils are well-drained loamy soils rich in organic matter with pH range of 5-7 and climatic conditions that enable farmers to produce maize in two seasons (major and minor). The climatic condition and availability of forest land to farmers enhance maize production in the area. The Dormaa Municipality is divided into four agricultural zones and with the assistance of Extension agents in Dormaa, four communities (Amasu, Koradaso, Duasidan, and Suromani) were selected with maize as the main economic activity. Figure 1 is a map of Dormaa Municipality showing the four communities studied.

Figure 1
Map of Dormaa Municipality, Ghana, Showing Study Sites.



Source: Ghana Statistical Service, 2014.

Data Collection Procedure and Methods

This study used a cross-sectional research design to ascertain farmers' stages of adoption and their perceptions of the hermetic bags. A cross-sectional study is used when a given group is studied at the same point in time (Ary et al., 2019). A structured questionnaire was used to collect data from smallholder maize farmers in Dormaa, Ghana, in July 2021. A multistage random sampling technique was used. In the first stage, a major maize growing area, Dormaa in the Middle Belt of Ghana, was selected. The Middle Belt and Dormaa, a municipality in that region, was identified by the USAID Feed the Future Postharvest Innovation Lab (PHLIL) as a major maize production area (Opit et al., 2014). In the second stage, we selected four communities (Amasu, Koradaso, Duasidan, and Suromani) from the four agricultural zones (Amasu, Koradaso, and Nsuhia and Agyemangkrom zone), one from each zone, where maize is the main economic activity. It was followed by a systematic sampling of maize farmers from the four communities. Respondents interviewed were either the household principal male or female member who made household decisions and managed the farm. We started with the first house at the entrance into the community and surveyed one adult (male or female) involved in maize production in every third house (1,4,7,10, etc.). We skipped houses where no adult member was engaged in maize production. We spoke to either the man or woman whose primary occupation was maize farming. In the case where both partners produce maize, we spoke to one of the partners. In some cases, we had to ask the man if we could speak to the wife if both partners were involved in maize farming. This was based on personal discretion and culture.

The selection of participants was based on farmers who had been active in maize production in the last two years. We surveyed 217 farmers in the four communities (Amasu - 51; Duasidan - 55; Koradaso - 53; and Suromani - 58) selected for the study. Data collection and analysis were done according to the ethical principles of research with human subjects after obtaining Institutional Review Board (IRB) approval. When the participant agreed to be interviewed, we commenced with the survey questions using an enumerator who spoke the local language.

Instrument

The survey instrument contained closed-ended questions and statements organized into two sections. The statements of the first section focused on identifying the position of the farmers in the innovation-decision process. Statements to understand farmers level of awareness and usage (adoption) of the hermetic bags were developed. Rogers's (2003) five stages in the innovation-decision process formed the theoretical base for this section. Li (2004) added the "no knowledge" stage to identify respondents with no knowledge of an innovation. Statement such as “I have never heard about hermetic storage bags” was used to identify farmers at the “no knowledge” stage. The “no knowledge” stage was included as the first stage in the innovation-decision process. While statements such as “I have used hermetic bags long enough to understand that I will keep using them” helped us to understand farmers who were at the confirmation stage – the last stage in the innovation-decision process. Participants were asked to select only one statement that best reflected their current stage in the innovation-decision process.

The second section was designed to measure the innovation characteristics of the hermetic bags as defined by Rogers (2003): relative advantage, compatibility, complexity, observability, and trialability. The innovation characteristics were rated using a five-point Likert-type scale (1 = *strongly disagree* to 5 = *strongly agree*). The questions about innovation characteristics were designed by adopting and modifying Moore and Benbasats' (1991) instrument and Ulmer and Lambert's (2020) instrument, which measured perceptions of an innovation characteristic.

A team of experts consisting of five professors at Iowa State University reviewed and revised the questionnaire to determine content validity. It was also reviewed by our team of enumerators in Ghana to adjust any terminology or answer choices that would not make sense in the local community. Cronbach's alpha was used to determine internal consistency of the five scales measuring perceptions of the attributes of hermetic bags. Table 1 presents the post-hoc reliability test results of the Cronbach's Alpha coefficient based on participants' perceptions of hermetic storage bag technology. Following Lance et al. (2006), a cut-off criterion of 0.70 or higher is acceptable. The summated rated scales had sufficient internal consistency and reliability. However, a range of 0.5 to 0.6 (modest reliability) is acceptable if the results are for research purposes and to make decisions (Ary et al., 2019). Using this guidance, all constructs were found reliable as shown in Table 1.

Table 1
Reliability Test

Construct	Number of Items	Cronbach's alpha
Relative advantage	8	0.772
Compatibility	5	0.563
Complexity	7	0.773
Trialability	4	0.743
Observability	4	0.840

Estimation Strategy

The results of the five innovation attributes (relative advantage, compatibility, complexity, observability, and trialability) were obtained by summing up all items in each component. Indices were created and normalized to range from 0 to 1. Both descriptive statistics and logistic regression were used to analyze and present results. Precisely, the use of logistic regression helps in predicting the likelihood or probability of the farmers adopting hermetic storage bags, given the set of associated innovation characteristics. The data analysis was done using STATA version 16 software.

Results

Table 2 presents the number of farmers surveyed in the four communities in Dormaa showing the number and proportion of adopters and non-adopters of hermetic bags. As observed, Suromani had the highest number of adopters (*f* = 44, 20.28%), and Amasu had the least number of adopters (*f* = 15, 6.91%) of hermetic bags in the study area. The result showed 58.06% of farmers had adopted the hermetic bags, while 41.94% were non-adopters. For this study adopters were considered those who had made the decision to use the hermetic bags and were using the bags to store their maize.

Table 2

Adopters and Non-Adopters in the Study Area

Community	Adopters		Non-adopters		
	f	%	*f*	%	Total, *f* (%)
Amasu	15	6.91	36	16.60	51 (23.5)
Duasidan	39	17.97	16	7.37	55 (25.35)
Koradaso	28	12.90	25	11.52	53 (24.42)
Suromani	44	20.28	14	6.45	58 (26.73)
Total	125	58.06	91	41.94	217 (100.00)

Note. One participant is identified as a rejector and is therefore not accounted for in either the adopter or non-adopter data.

The findings show, of the total number of farmers interviewed, more than half of the respondents were male (58.41%), and 64% had adopted the hermetic bags compared to 36% of female adopters. Respondents' ages ranged from 21-80 years, with a mean age of 44.05 (*SD* = 10.98). Most adopters (36%) were in the 40-49 age group. Also, most respondents had a primary (28.5%) or junior secondary education (28.5%).

Furthermore, about 67% of the study participants had received training on hermetic storage bags, with about 86% served by Extension in the past two years. Most respondents (67.17%) who received training in hermetic bags were using the bags to store their maize.

The results revealed that approximately 31% of respondents who owned farmland adopted the hermetic bags. About 40% of the farmers indicated they work on one to three hectares of land, and approximately 36% of farmers indicated their farm size is between four and six hectares. Moreover, a majority of adopters work on four to six hectares of farmland (*f* = 56, 25.81%) and one to three hectares of farmland (*f* = 47, 21.66%). The chi-square (22.66) has a p-value of 0.00, which indicate that adoption is associated with farm size. Table 3 presents the results of adopters and non-adopters based on respondents' farm size.

Table 3
Distribution of Adopters and Non-Adopters Based on Farm Size

Farm size (Ha)	Adopters		Non-adopters		
	f	%	*f*	%	Total, *f* (%)
Less than 1 hectare	4	1.84	19	8.76	23 (10.60)
1-3 hectares	47	21.66	40	18.43	87 (40.09)
4-6 hectares	56	25.81	23	10.60	79 (36.41)
7-9 hectares	8	3.69	4	1.84	12 (5.53)
9 and more hectares	11	5.07	5	2.30	16 (7.37)

Note. Chi-square = 22.66; Pr = 0.00

Maize Farmers' Rate of Adoption of Hermetic Storage Bags

The results in Table 4 show a plurality of respondents were at the confirmation stage (*f* = 102, 47%) indicating they have used the bags long enough to understand, and they will keep using the bags to store maize. The results reveal 37 respondents (17.05%) had no knowledge about hermetic bags. There was one rejector, and the remaining 77 (35.5%) were dispersed across stages two to five in the innovation-decision process. A large majority of those were at stages two and three.

Table 4
Distribution of Participants by their Current Stage in the Innovation Decision Process

Stages	Response	*f*	%
No knowledge	I have never heard about hermetic storage bags	37	17.05
Knowledge	I know a few things about hermetic bags, but I have not used it or know if I will use them or not.	25	11.52
Persuasion	I am still learning how to use hermetic bags, but I haven't decided to use them to store my maize or not.	29	13.36
Decision to adopt	I have tried using hermetic bags to store my maize and I will keep using them.	11	5.07
Decision to reject	I have tried using hermetic bags and I have decided not to continue using them again.	1	0.46
Implementation	I have used hermetic bags and I am still at the point of understanding how it fits my maize protection.	12	5.53
Confirmation	I have used hermetic bags long enough to understand that I will keep using them.	102	47.00
Total		217	100.00

Influence of Innovation Attributes on the Adoption of the Hermetic Storage Bags

Indexes for each innovation attribute for all questions within the index were summed up to obtain the average of these indexes (see table 5). Indexes were created and normalized, and the index means ranged from 0 to1; with 0.0 (strongly disagree) to 1.0 (strongly agree). Observability had the highest overall mean of 0.81 (SD = 0.08). This is followed by trialability with an overall mean of 0.63 (SD =

0.14). Relative advantage had an overall mean of 0.58 (SD =0.24). Compatibility had an overall mean of 0.58 (SD = 0.27). Finally, complexity had an overall mean of 0.58 (SD = 0.17).

Table 5
Index Means, Standard Deviations of the Five Innovation Attributes for Adopters and Non-Adopters

Innovation attribute	Adopters		Non-adopters		Overall	
	M	SD	M	SD	M	SD
Relative advantage	0.82	0.16	0.33	0.31	0.58	0.24
Compatibility	0.78	0.20	0.38	0.33	0.58	0.27
Complexity	0.71	0.25	0.45	0.08	0.58	0.17
Trialability	0.81	0.24	0.44	0.03	0.63	0.14
Observability	0.87	0.15	0.75	0.00	0.81	0.08

Next, we calculated a logistic regression for the five innovation attributes (see table 6). The coefficient of relative advantage is positive and significant at 1%, implying that as relative advantage increases, the log odds of farmers adopting the hermetic bag innovation is 1.328 times higher, everything being equal. The marginal effects, however, show that although a unit increase in perceived relative advantage increases the probability of adopting the hermetic bag by 0.016 percent points, such increments are insignificant. Similarly, the influence of compatibility is positive and significant at 10%, indicating that a unit increase in the compatibility index increases the log odds of farmers adopting the hermetic bag innovation by 0.560 with a marginal effect of 0.007 percent points.

Table 6
Logistic Regression for the Five Innovation Characteristics

Innovation attributes	Coefficients	Marginal effects
Relative Advantage	1.328*** (0.345)	0.016 (0.011)
Compatibility	0.560* (0.304)	0.007* (0.004)
Complexity	-0.384* (0.230)	-0.005 (0.003)
Trialability	0.155 (0.209)	0.002 (0.003)
Observability	-0.637 (0.481)	-0.008* (0.004)
Constant	4.992** (2.146)	

Note: Log likelihood=-5.49; Wald chi-squared=88.12; Prob > chi squared=0.00; Pseudo R^2*=0.5991. The figures in parentheses are standard errors; *** = p<0.01, ** = p<0.05, * = p<0.1.*

Meanwhile, the coefficient of complexity is negative and significant at 10%, implying that the log odds of adopting the hermetic bag innovation following increased perceived complexity in the system decreases by 0.384 percent points, but with the marginal effect being insignificant. Furthermore, the findings show that although observability decreases the log odds of adopting the innovation, trialability has the potential to increase it, the influence of trialability is insignificant, but the marginal effect of observability is significant at 10%.

In a nutshell, the findings show that the greater the relative advantage the hermetic bag innovation provides the farmer, and the more compatible it is for farmers to store their maize, the more likely they are to adopt the bags. But the more complex the innovation, the less likely they are to adopt the innovation.

There are potential and unknowable confounding variables that could exist in the data and other outside factors that could influence farmers' adoption of hermetic bags. For instance, people who had attended the PHLIL training might have had more information that could have influenced them to adopt the hermetic bags compared to those who did not attend the PHLIL training in the area.

Discussions, Conclusions, and Recommendations

The aim of this study was to identify where farmers are in the adoption of the hermetic bags and farmers' perceptions of the hermetic bags in Dormaa, Ghana. Rogers's (2003) innovation-decision process (knowledge, persuasion, decision, implementation, and confirmation) was used to identify farmers' stages in the adoption process. As suggested by Li (2004), we added "no knowledge" as a sixth stage to the innovation-decision process initially.

In assessing farmers' rate of adoption of hermetic bags by identifying farmers' stages in the adoption process, the results reveal that 47% of farmers are at the confirmation stage. At the confirmation stage, adopters need reinforcement for the decision made to not reverse the decision (Rogers, 2003). On the other end, about 17% of farmers were unaware of the innovation. So, more than a third were somewhere in the knowledge, persuasion, or decision stage.

This finding is therefore an indication of the fact that, although extension, NGOs, and other stakeholders are providing hermetic storage technology information and doing training in the study area, the dissemination of information and knowledge about the hermetic storage technology remains inadequate. Early adopters and opinion leaders have a great influence on early and late majority adopters (Rogers, 2003).

In the analysis of maize farmers' perceptions of hermetic bags using Rogers's (2003) five innovation attributes (relative advantage, compatibility, complexity, trialability, and observability), the logistic regression revealed relative advantage, compatibility, and complexity to be significant predictors of adoption. The results demonstrate a positive and significant result for relative advantage, indicating that the greater the benefits of using the bags, the greater the likelihood of adoption. This is because, the more a person perceives an innovation to be beneficial than the old method, the more likely they are to adopt an innovation (Rogers, 2003). This corroborates the findings by Lamm et al. (2017) who found relative advantage as a decisive factor influencing adoption.

Compatibility was found to be positive and significant, indicating that as perceived compatibility increases, farmers' likelihood to adopt hermetic bags increases. The significant result indicates that perceived compatibility is a significant determinant of adoption in line with the findings of Warner et al. (2020). The results for complexity although negative was significant, implying that the more complex the innovation is, the lesser the likelihood of farmers adopting hermetic bags. This affirms a study by Warner et al. (2020), that the less complex it is for an individual to use and implement an innovation, the more likely they will adopt the technology.

Overall, farmers do find the hermetic bags useful. The results show that about 47% of farmers were at the confirmation stage, having used the hermetic bags long enough and personally observed the effectiveness of the bags and have decided to keep using the hermetic bags. Also, approximately 17% of respondents had "no knowledge" about hermetic bags. Furthermore, the results show that one of the communities (Amasu) had the least number of adopters. This result indicates a need to develop training programs to increase awareness and the rate of adoption of hermetic bags by farmers in Dormaa.

Based on these, the study recommends more training should be done in the study area. Given that the pandemic brought to a halt the yearly training done by the PHLIL engagement team in Dormaa, Ghana, it is recommended that the Feed the Future Post-harvest Loss Innovation Lab re-launch these trainings and develop a strategy to follow up with personnel trained to provide PHLIL with feedback about the training they do with the farmers. During the training sessions, Extension agents, NGOs, and other stakeholders should provide information about distribution centers to adopters and potential adopters to get farmers informed of sales points of the bags. At the same time, by providing appropriate guides and instructions, the innovation will easily be adopted.

There is a need for increased dissemination of information of hermetic storage bags. Extension agents in Dormaa should provide information and organize training about agricultural activities in Dormaa. It is also recommended for extension officers in Dormaa to target their post-harvest loss training toward the community Amasu as it has the least number of adopters.

The Ministry of Food and Agriculture (MoFA), Extension agents in Ghana, NGOs and other stakeholders disseminating information to enhance the adoption of hermetic storage technology, must consider the perceived characteristics of the hermetic bag innovation. Accordingly, these stakeholders should focus their efforts on relative advantage and compatibility of the hermetic bags, at the same time acknowledging, observability, trialability, and complexity in their dissemination process. Extension should ensure that farmers learn how to effectively use and store their maize in hermetic bags. This could entail providing training for farmers to observe or use items hands on to boost adoption of the innovation.

For future research, we recommend that the Technology Acceptance Model (TAM) be adopted since it adds on adopters' perceived image of an innovation and subjective norm as additional constructs to Rogers's (2003) five innovation attributes to examine farmers' acceptance and use of the hermetic storage bags in Dormaa, Ghana.

References

Adesina, A. A., & Zinnah, M. M. (1993). Technology characteristics, farmers' perceptions, and adoption decisions: A tobit model application in Sierra Leone. *Agricultural Economics*, *9*(4), 297-311. https://doi.org/10.1111/j.1574-0862.1993.tb00276.x

Almobarraz, A. (2007). *Perceived attributes of diffusion of innovation theory as predictors of internet adoption among the faculty members of Imam Mohammed Bin Saud University (Publication No. 3276419*) [Doctoral dissertation, University of North Texas]. ProQuest Dissertations and Theses Global.

Ary, D., Jacobs, L. C., Irvine, S. C., & Walker, D. (2019). *Introduction to research in education* (10th ed.). Cengage Learning. Inc.

Ashitey, E., & Archibald, D. (2018, February 2). Grain and feed update. USDA Foreign Agricultural Service. *Gain Report. Global Agricultural Information Network*. https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Grain%20and%20Feed%20Update_Accra_Ghana_2-2-2018.pdf

Baributsa, D., Bakoye, O. N., Ibrahim, B., & Murdock, L. L. (2020). Performance of five postharvest storage methods for maize preservation in Northern Benin. *Insects*, *11*(8), 541. https://doi.org/10.3390/insects11080541

Baributsa, D., & Ma Cristine, C. I. (2020). Developments in the use of hermetic bags for grain storage. In D. Maier (Ed.), Advances in postharvest management of cereals and grains (pp.1-28). Bd Burleigh Dodds Publishing. http://dx.doi.org/10.19103/AS.2020.0072.06

Baributsa, D., & Njoroge, A. W. (2020). The use and profitability of hermetic technologies for grain storage among smallholder farmers in eastern Kenya. *Journal of Stored Products Research*, *87*, 101618. https://doi.org/10.1016/j.jspr.2020.101618

Danso, J. K., Osekre, E. A., Manu, N., Opit, G. P., Armstrong, P., Arthur, F. H., ... & Mbata, G. (2017). Moisture content, insect pests and mycotoxin levels of maize at harvest and post-harvest in the Middle Belt of Ghana. *Journal of Stored Products Research*, *74*, 46-55. https://doi.org/10.1016/j.jspr.2017.08.007

Danso, J. K., Osekre, E. A., Opit, G. P., Manu, N., Armstrong, P., Arthur, F. H., ... & McNeill, S. G. (2018). Post-harvest insect infestation and mycotoxin levels in maize markets in the Middle Belt of Ghana. *Journal of Stored Products Research, 77*, 9-15. https://doi.org/10.1016/j.jspr.2018.02.004

Darfour, B., & Rosentrater, K. A. (2016, July 17-20). Agriculture and food security in Ghana [Paper Presentation]. *The ASABE Annual International Meeting, Orlando, Florida, United States.* https://lib.dr.iastate.edu/abe_eng_conf/478

Ghana Statistical Service. (2014). *2010 population and housing census: District analytical report, Dormaa Municipality.* https://www2.statsghana.gov.gh/docfiles/2010_District_Report/Brong%20Ahafo/Dormaa%20Municipal.pdf

Gockel, R., Hampton, K., & Gugerty, M. K. (2009). Storage, transportation and aggregation of agricultural products for smallholder farmers in Sub-Saharan Africa. *Prepared for the Agricultural Policy and Statistics Division of the Bill and Melinda Gates Foundation*, 36, 1-33. https://epar.evans.uw.edu/sites/default/files/Evans%20UW_Request%2028_Structured%20Demand_08-10-2009.pdf

Godfray, H. C. J., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., ... & Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. *Science*, *327*(5967), 812-818. https://doi.org/10.1126/science.1185383

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

Lamm, A. J., Warner, L. A., Taylor, M. R., Martin, E. T., White, S. A., & Fisher, P. (2017). Diffusing water conservation and treatment technologies to nursery and greenhouse growers. *Journal of International Agricultural and Extension Education*, *24*(1), 105-119. https://doi.org/10.5191/jiaee.2017.24110

Lance, C. E., Butts, M. M., & Michels, L. C. (2006). The sources of four commonly reported cutoff criteria: What did they really say? *Organizational Research Methods*, *9*(2), 202-220. https://doi.org/10.1177/1094428105284919

Li, Y. (2004). *Faculty perceptions about attributes and barriers impacting diffusion of web-based distance education (WBDE) at the China Agricultural University* (Publication No. 3141422) [Doctoral dissertation, Texas A & M University]. ProQuest Dissertations and Theses Global.

Manu, N., Osekre, E. A., Opit, G. P., Arthur, F. H., Mbata, G., Armstrong, P., ... & Campbell, J. (2019). Moisture content, insect pests and mycotoxin levels of maize on farms in Tamale environs in the northern region of Ghana. *Journal of Stored Products Research, 83*, 153-160. https://doi.org/10.1016/j.jspr.2019.05.015

Moore, G. C., & Benbasat, I. (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192-222. https://doi.org/10.1287/isre.2.3.192

Nganga, J., Mutungi, C., Imathiu, S., & Affognon, H. (2016). Effect of triple-layer hermetic bagging on mould infection and aflatoxin contamination of maize during multi-month on-farm storage in Kenya. *Journal of Stored Products Research*, *69*, 119-128. https://doi.org/10.1016/j.jspr.2016.07.005

Opit, G. P., Campbell, J., Arthur, F., Armstrong, P., Osekre, E., Washburn, S., ... & Reddy, P. V. (2014, November). Assessment of maize postharvest losses in the Middle Belt of Ghana [Conference Session]. *The 11th International Working Conference on Stored Product Protection*. http://spiru.cgahr.ksu.edu/proj/iwcspp/pdf2/11/132.pdf

Robertson, M. J., Llewellyn, R. S., Mandel, R., Lawes, R., Bramley, R. G. V., Swift, L., ... & O'Callaghan, C. (2012). Adoption of variable rate fertiliser application in the Australian grains industry: Status, issues and prospects. *Precision Agriculture*, *13*(2), 181-199. https://doi.org/10.1007/s11119-011-9236-3

Rodriguez, M. T., Roberts, T. G., & Harder, A. (2018). Exploring the influence of innovation characteristics on the adoption of a water and input saving technology in the Jordan Valley: Implications for community extension workers. *Journal of International Agricultural and Extension Education*, *25*(3), 81-95. https://*doi.org/10.5191/jiaee.2018.25306*

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). The Free Press.

Silva, G. (2018). Feeding the world in 2050 and beyond – Part 1: Productivity challenges. *Michigan State University Extension agriculture*. https://www.canr.msu.edu/news/feeding-the-world-in-2050-and-beyond-part-1

Sheahan, M., & Barrett, C. B. (2017). Food loss and waste in Sub-Saharan Africa: A critical review. *Food Policy*, *70*, 1-12. https://doi.org/10.1016/j.foodpol.2017.03.012

Sirajuddin, Z. (2019). *The adoption of Cyber-Extension in Indonesia: Impact of extension agents' perception of cyber extension's innovation attributes and information and communication technology (ICT) proficiency* (Publication No. 17319) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global.

Taylor, C. N. W. (2015). *Examining e-extension: Diffusion, disruption, and rate of adoption among Iowa State University Extension and Outreach professionals* (Publication N0. 14427) [Doctoral dissertation, Iowa State University]. ProQuest Dissertations and Theses Global.

Tubbs, T., Baributsa, D., & Woloshuk, C. (2016). Impact of opening hermetic storage bags on grain quality, fungal growth and aflatoxin accumulation. *Journal of Stored Products Research*, *69*, 276-281. https://doi.org/10.1016/j.jspr.2016.10.003

Ulmer, J. D., & Lambert, M. D. (2020, April 20-23). *Creating an instrument to measure technology adoption in Africa.*, [2019-2545]. AIAEE Conference, St. Petersburg, FL. United States.

Warner, L. A., Lamm, A. J., & Silvert, C. (2020). Diffusion of water-saving irrigation innovations in Florida's urban residential landscapes. *Urban Forestry & Urban Greening*, *47*, 126540. https://doi.org/10.1016/j.ufug.2019.126540