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Research Article

Studies on Effects of Purdue Improved Crop Storage (PICS) Bags in Reducing Post-Harvest Loss (PHL) in Maize Storage in Nigeria

Bamikole Ayedun*

International Institute of Tropical Agriculture IITA, Ibadan, Nigeria

***Corresponding Author:** Bamikole Ayedun, International Institute for Tropical Agriculture IITA, Ibadan, Nigeria.

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Abstract

In the year 2014, a survey data was collected from 2010 randomly selected grain farmers, out of which 1652 were farmers that produced and stored maize. This study estimated and compared post-harvest losses (PHL) of stored maize grains through Purdue Improved Crop Storage (PICS) bag and other storage methods and also determined factors influencing PHL. The result shows that insect constituted 68.3% source of PHL. PHL for stored maize grain were 6.6% for traditional granary, 4.2% for woven bag, 3.6% for airtight containers, 3.1% for improved granary and with the least being 0.1% for PICS bag. Tobit model was estimated with PHL as dependent variable; independent variables like 'insect attack, stored shelled maize and storing at homes instead of warehouses' increased PHL, while the 'use of PICS bag, application of protectants to maize in storage and storage of improved maize variety reduced probability and intensity of PHL'. Considering marginal effect (dy/dx) estimate, it means that insect attack was significant ($p < 0.01$) and increased probability and intensity of PHL by 9.8%. On the other hand, use of PICS bag for storage reduced ($p < 0.01$) probability and intensity of PHL by 7%, although 'use of insect protectants' reduced PHL, it is not recommended due to its health hazard to man and livestock. While PICS bag caused reduction in probability and intensity of PHL, Logit model was estimated to determine factors influencing the use of PICS bag; result shows that an increase in the use of PICS bag reduced probability of losses through insect attack ($p < 0.01$) by 10%. More than 50% of the farmers complained of inaccessibility of the bag and its high cost. There is need for intensified awareness creation and making PICS-bag available to maize farmers with prospective storage intentions at affordable prices.

Keywords: Maize Storage; Post-Harvest Losses; Logit Model; Marginal Effect

Introduction

Maize (*Zea mays*) is a cereal crop that is grown widely throughout the world in a range of agro-ecological environments. Maize is the most important cereal crop in sub-Saharan Africa (SSA) and an important staple food for more than 1.2 billion people in SSA and Latin America (www.iita.org). Maize is grown as forage, silage or grain to feed livestock. It is also a significant ingredient of some commercial animal food products such as feed, dairy poultry, piggery and dog food among other. It is also used for production of dough ball for fish bait [1]. More maize is produced annually than any other grain (www.iita.org). Africa harvests 25 million hectares of maize with Nigeria being the largest producer in SSA [2].

Improving staple crop production is widely viewed as crucial for increasing food security and reducing poverty in SSA. However, it is essential to recognize that food security challenges do not simply end at harvest [3]. Smallholder farmers in SSA face numerous challenges after their grain leaves the field. Farmers who store grain may experience significant quantity losses due to damage from rodents, insect pest and mold and subsequent price discounts for damaged grain, these losses are types of post-harvest loss [4-6]. Post-harvest loss (PHL) can be defined as the degradation in both quantity and quality of a food production from harvest to consumption. Quality losses include those that affect the nutrient/caloric composition, the acceptability, and the edibility of a given product. These losses are generally more common in developed countries [7]. In this context, quantity losses refer to those that result in the loss of the amount of a product. Loss of quantity is more common in developing countries [8]. After harvesting, farmers do not store their maize properly resulting into PHL which includes both qualitative losses that affects the nutrient/calorie content, the acceptability, and the edibility of the maize and quantitative losses that results in the reduction of the amount of maize. There are various ways by which maize can be lost after harvest, these are: due to insufficient drying after harvesting, maize can develop moulds thereby resulting to losses, during threshing and winnowing which can cause losses from broken grains. Poor storage methods can cause loses by the action of moulds, insects, rodents etc. during transportation, processing [9].

According to Folayan [1]. PHL can be categorized into three: Physical factor which includes temperature and moisture content of the stored grains, biological factors includes insects and mites, birds, rodents and other wildlife, micro-organism(fungi, mould and bacteria), engineering and mechanical factors include types and efficiency of harvesting tools, equipment and machines; primary processing equipment and machines; drying and storage structures; type and efficiency of non-farm transport, farming system and storage and marketing system etc. [1]. PHL occur between harvest and the moment of human consumption. They include on-farm losses, such as when grain is threshed, winnowed and dried, as well as losses along the chain during transportation, storage and processing [10]. It is a measurable quantitative and qualitative food loss in the postharvest system [11]. The milling losses in insect-damaged grain are even higher as more breakage and powdering occur with such grain. In order to provide for the food security of the citizenry, surplus grains are pre-served in storage to serve amongst others, as a source of domestic food supply throughout the year (consumption), to generate revenue for the farming families (farm income) and seed for the following year's crop (seeds) among others. After harvest or purchasing those to be used as food or sold at off season when prices are better are stored for various length of time. At storage there is the need to provide protection from common storage loss-agents: Insect, rodents, moulds and offer reasonable protection from theft.

Different storage method for maize had been identified which are: Synthetic fertilizer bags, on a raised platform on the farm, over the fire place, constructed crib, ceiling, clay pot, rhumbu, oba, bottles, bare floor, baskets (bamboo or plastic), drum, on a tree and sunny room [12]. Also, gourds, mud-silo, traditional cob-storage, tin, nylon, plastic container and earthen clay pot [13]. traditional granaries, metal silos, mud silo, earthen clay pot). According to FAO [14]. storage methods for maize was classified into temporary storage methods which includes: aerial storage, on the ground and floors and open timber platforms, and long-term storage methods which includes: storage baskets (cribs), calabashes, bags, gourds, earthenware pots, jars, solid wall bins, underground storage, sacks, metal or plastic drums, concrete/cement silos, metal silos, synthetic silos, and ferro cement bin. Nduku [15]. categorized maize storage structures as follows: storage over fire, basket, large pot, metal silo, traditional crib/granary (cylindrical) improved granaries, woven bag etc. Maize is more difficult to store than other cereals at harvest because of its high moisture content at harvest time. At storage there is need to choose an effective storage method to provide protection from common storage loss-agents. For convenience, storage structures are categorized into two broad types; ventilated storage structures (non-hermetic) and unventilated storage structures (hermetic). Non-hermetic ones may include - the cribs, bags/sacks, on-farm storage structure, warehouse storage using bags. Hermetic includes silo, plastic bag, metal drums, jerry can, PICS bag, underground granaries, earthen silos among others; according to Murdock., *et al.* [16] these containers are suitable for long-term storage.

PICS Bagging is a technology developed by Purdue University in collaboration with African researchers, known as Purdue Improved Crop Storage (PICS), is literally 'bagging' the problem of grain weevils by using non-chemical, hermetic storage. The bag allows very little air from outside to get to the grains. The weevils consume the small amount of oxygen available and emit carbon dioxide (CO_2). In just a few hours a low oxygen and enriched carbon dioxide (CO_2) environment is created which stops the bruchids from causing the damage. The weevils eventually die after a long period [16]. Jackai [17] and Aitchedji [18]. reported that use of insecticides to protect grains in storage is very controversial, because chemical residues are erroneously feared to persist in the grain after the cooking and thus poses health challenges, in addition, households may have their food safety and health jeopardized when they store grain if they apply storage chemicals inappropriately [19]. All of these storage challenges undermine household income, food security and nutrition, food safety, and health. Despite the danger poses by insectides, most of the legume and cereal grains sold in the market after three months or more of harvest is generally treated with insecticides [20]. In the year 2014/15, survey was conducted including 2010 grain farm households in Nigeria to assess the efficiency of major storage technologies available to maize grains' farmers. Four storage technologies were compared including traditional granaries and woven bag that are non-hermetic; and airtighdrum/can, and PICS bag that are hermetic in nature. Variables like storage duration period, percentage PHL, and degree of infestation by insect pest were considered in comparing the technologies. In addition, determinants of PHL and storage decision using PICS bag were accessed using econometric methods.

Methods

This study was conducted in five states of Nigeria: Gombe, Benue, Plateau noted for maize production in Northern zone and Imo and Osun states in the Southern states which are not renowned for maize production see (Figure 1). This section describes the study area; then data collection and finally the analytical tools used are presented.

The Study Area

Northern Region/Zones

Gombe state: It is one of the 36 states of the federal republic of Nigeria, located in the centre of the north east of the country on latitude 9"30' and 12"30'N, longitude 8"5' and 11"45'E. [21]. (http://gombestate.gov.ng/2012). The State, nicknamed the Jewel of Excellence, was formed in October 1996 from part of the old Bauchi State by the Abacha military government. Being it located in the north eastern zone, right within the expansive savannah allows the state to share common borders with the states of Borno, Yobe, Taraba, Adamawa and Bauchi. The state has an area of 20,265 km^2 and a population of around 2,353,000 people as of 2006 (NPC 2006). Gombe has two distinct climates, the dry season (November-March) and the rainy season (April-October) with an average rainfall of 850 mm. Farming is the main occupation of the people of the state and crops produced include cassava, yam, rice, maize, guinea corn, beans, soya beans, asha and millet [22].

Benue State: It is one of the 36 states of Nigeria located in the North-Central part of Nigeria. The State has 23 Local Government Areas, and its Headquarters is Makurdi. Located between Longitudes 60 35'E and 100 E and between Latitudes 60 30'N and 80 10'N. The State has abundant land estimated to be 5.09 million hectares. This represents 5.4 percent of the national land mass. Arable land in the State is estimated to be 3.8 million hectares. This State is predominantly rural with an estimated 75 percent of the population engaged in rain-fed subsistence agriculture. The state is made up of 413,159 farm families and a population of 4,219,244 people. These farm families are mainly rural. Farming is the major occupation of Benue State indigenes. Popularly known as the "Food Basket" of the Nation, the State has a lot of land resources. For example, cereal crops like rice, sorghum and millet are produced in abundance. Roots and tubers produced include yams, cassava, cocoyam and sweet potato. Oil seed crops include pigeon pea, soybeans and groundnuts, while tree crops include citrus, mango, oil palm, guava, cashew, cocoa and Avengia spp. [23]. The state accounts for over 70% of Nigeria's Soybean production [24].

Plateau state: This state lies between latitudes 80N and 100E and longitudes 70E and 110E of the prime meridian. The Plateau highland stands at an average height of 1200 meters above mean sea level. The mean temperature in the Southern part of the state varies from 31oC to about 140C on the Plateau while the annual rainfall varies from 131.75 mm in the Southern part to 146.00 mm on the Jos plateau. Though situated in the tropical zone, the climate on Jos Plateau and its environs simulates that of the temperate region while the Southern part is much more tropical. With adequate fertilizer supplement and the use of improved varieties, crop varieties like maize, Irish potato, cocoyam, upland rice, sorghum and vegetables are being produced. Livestock types found in the state are cattle, sheep, goats, pigs and poultry [25].

Southern Region/Zones

Imo state: It is in the Niger Delta region, is one of the 36 states of Nigeria and lies in the South East of Nigeria with Owerri as its capital and largest city [26] (https://en.wikipedia.org/wiki/Imo_State) Located in the south-eastern region of Nigeria, it occupies the area between the lower River Niger and the upper and middle Imo River.]Imo State is bordered by Abia State on the East, River Niger and Delta State to the West, Anambra State on the North and Rivers State to the South. The State lies within latitudes 4°45'N and 7°15'N, and longitude 6°50'E and 7°25'E with an area of around 5,100 km2. Imo state is located in the South - Eastern area of Nigeria and shares boundaries with Anambra, Abia Delta and Rivers states (https://en.wikipedia.org/wiki/Imo_State). The state has a total land area of about 19,000 square kilometers and a population of about 3.38 million people [27,28]. The people of the state are mostly rural which makes their occupational distribution tilted towards agricultural production. The climate is of two types: the dry and wet seasons with intervening cold and dry harmattan period usually experienced during December and January. The state has an annual rainfall ranges from 2000 to 2500 mm while maximum average temperature ranges between 30 - 35°C [26]. With this climatic pattern and few sizeable expanses of arable land due to high population density, the farmers in the area grow crops like oil palm, raffia palm, rice, groundnut, melon, cotton, cocoa, rubber, maize, fruits etc. food crops such as yam, cassava, cocoyam, vegetables and maize are also produced in large quantities [29]. Hence, there are a total of 303,333 farm families in agricultural production in the state [26].

Osun state: It is located in southwestern Nigeria, between latitudes 7.0° and 9.0°N, and longitudes 2.8° and 6.8°E. The topography is rolling hills and lies between 300 and 600 m above sea level. Average rainfall decreases from 1475 mm in the forest belt in the southern sections of the state to 1125 mm in the savannah section to the north. Mean annual temperature ranges from 27.2°C in June to 39.0°C in December. Soil types are varied but most contain a high proportion of clay and sand and are mainly dominated by the lateritic series. The State is mainly agrarian. Food crops grown in the area include maize (*Zea mays*), yam (*Dioscorea* spp), cassava (*Manihot esculenta*), cocoyam (*Colocasia* spp), rice (*Oryza sativa*) and vegetables (*Amaranthus* spp). The permanent crops cultivated include cocoa (*Theobroma cacao*), kolanut (*Cola nitida*) and oil palm (*Elaeis guinensis*). These crops are usually mixed or intercropped [30].

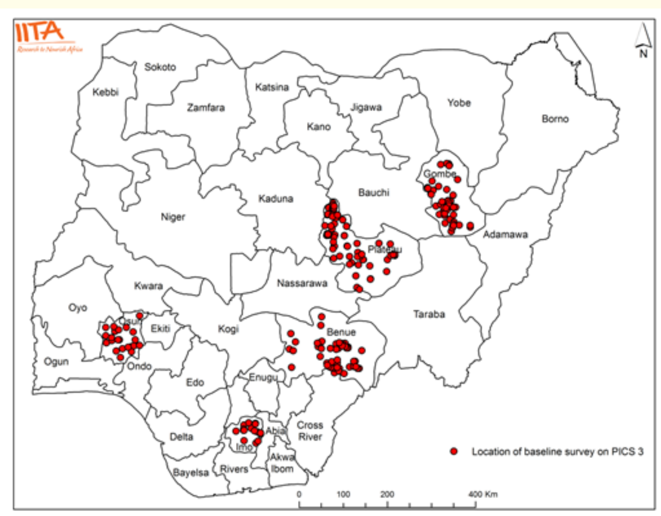

Figure 1: The study area locations in Nigeria.

Sampling

In this study, a multistage sampling technique was used; four zones were selected, 2 in the North (North East and North Central) and 2 in the South (South West and South East). The second stage was selection of LGAs from which communities where farmers growing grains were selected. Gombe state was selected in the North East, 40 LGAs were selected in Gombe state, and in each LGA a community was selected. In each community, 15 farmers producing grains were selected to make a total of 600 responding grains' farmers. In the same vein Benue was from North Central zone, 40 LGAs was sampled, in each of the LGAs, 15 farmers were selected to give a total of 600 for Benue state. Also, from North Central, Plateau state was selected and 30 LGAs was sampled from it. In each of the LGAs, 15 farmers were selected to give a total of 450 farmers for Plateau state. In the South East, 12 LGAs were selected from Imo state, a community each was taken from each of the LGAs and in each of the LGAs 15 farmers were selected to make a total 180 farmers that were growing grains. Likewise, same number of LGAs, communities and farmers were selected in Osun state to give a total of 180 grains' farmers. The overall total was 2010 farmers growing grains. Survey was conducted from October 2014 till January 2015 at the beginning of the storage period using structured questionnaire in electronic form (CAPI) using Surveybe designer; enumerators were used to capture information from farmers administering the questionnaire through survey be implementer. All data used in the analysis were based on 2014 production and storage period. Data were collected on socioeconomic characteristics of the respondents, production and storage of maize grains, methods/technologies for storing mentioned maize grains, consumption and sales of the grains among others. The interviews were conducted by enumerators trained on the use of Surveybe implementer software and facilitated by extension agents from states' Agricultural Development Programs (ADPs).

Data analysis

In this paper, descriptive statistics such as mean, standard deviation and frequency distributions were computed and used for household characterization. T-test statistics was used to determine statistical differences between two groups along various variables considered, while ANOVA model was used to do the same among groups that were more than two with Least Significant Difference (LSD) complementing it to specify where the difference was lying if there was any. In addition, Tobit model was specified to identify factors influencing post-harvest losses, while Logit model was used to determine factors affecting the use of PICS bags for maize grains' storage in the study areas. The models are specified below.

Model specification: Tobit model

The advantage of Tobit model in this paper was that it not only measured the probability of post-harvest loss of maize grains, but also took care of its intensity of loss [31]. From Tobin [32], the Tobit model is specified as follows:

Let Y = Probability & intensity of PHL and the dependent variable

Let Y* =a latent or unobserved variable (reflecting the combine effect of explanatory variables hindering or promoting PHL.

Y* is not observable and is related to the observed Y as follows:

$Y^* = \beta' X + e$

$Y = Y^* (\beta' X + e) \text{ if } Y^* > 0)$...(1)

$Y = 0 \text{ if } Y^* \leq 0$

X= a vector of explanatory variables

β= a vector of unknown parameters to be estimated

e= is independently and normally distributed random error terms.

Equation 1 represent a Tobit model of intensity of PHL. As [32] shown, the expected value of Y (intensity of PHL) in the model i.e. the whole model is

$$E(Y) = \beta' XF(z) + \sigma f(z) \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

but the expected intensity Y* of PHL among farmers that stored maize grain is given by

$$E(Y^*) = \beta' X + \sigma f(z)/ F(z) \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Or the expected value of Y for observation above the limit, here called Y*= Xβ plus expected value of the truncated normal term.

$$E(Y^*) = E(y/y>0)$$

$$= E(y/u > - X\beta$$

$$= X\beta + \sigma f(z)/F(z) \quad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Consequently, the basic relationship between the expected value of all observations E(Y) and the expected value condition upon being above the limit, E(Y*) is E(Y)= F(z)E(Y*)………………(5)

Where z= β'X (X=mean of explanatory variable)

F(z)= the cumulative normal distribution function evaluated at Z

f(z)= unit normal density

β= Unknown Tobit parameter to be estimated

σ= standard error of the error term to be estimated

Model specification: Logit model (LM)

LM is given in its estimable form using maximum likelihood estimation method and following Gujarati and Porter [33], the model is expressed implicitly as:

$$LM = Ln\ (Pi\ /1 - Pi) = Zi = \beta i + \beta\ \Sigma_k X_{ik} + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Where:

Ln (Pi/1- Pi)=log odd ratio

Pi = probability that a farmer used or not used PICS bags for his/her maize grain storage; it ranges from 0 to 1, and is non-linearly related to Zi;βi = constant term / intercept; bk = coefficients of explanatory variables; X_{ik} = K= 1, 2, ……n = independent variables (with Ith observation) and ε = error term with zero mean' as Zi ranges from -∞ to ∞, Pi ranges from 0 to 1; thus the dependent variable 'P' is 1 if a farmer used PICS bags for storing his maize grains and is '0' if not.

Empirical models - Tobit model and Logit model

Tobit model

Tobit analysis is devised by Tobin [32] in which it is assumed that the dependent variable has a number of its values clustered at a limiting value, usually zero. The Tobit technique uses all observation both those at the limit and those above it to estimate the regression line. The coefficients for variables in the model, β, do not represent marginal effects directly, but the sign of the coefficient will give the researcher information as to the direction of the effect. In this paper the coefficients obtained by using Tobit (beta coefficients) provide more information than is commonly realized. Tobit can be used to determine:

- changes in the probability of being above the limit
- changes in the value of dependent variable, if it is already above the limit.

Y= Y* (βX + e) if Y*> 0), where X is the vector of explanatory variables. Explicitly

$$Y_i(MAIZE\_PHL) = \beta_0 + \beta_1 GENDER_i + \beta_2 AGE_i + \beta_3 FAMILY\_SIZE_i + \beta_4 CREDIT_i + \beta_5 BICYCLE\_OWNERSHIP_i + \beta_6 MAIZE\_VARIETY_i + \beta_7 STORE\_COWPEA2014_i + \beta_8 MAIZE\_DRYING\_PERIOD_i + \beta_9 STORAGE\_DECISION_i + \beta_{10} PICS\_USAGE_i + \beta_{11} SALES\_STORAGE\_PERIOD_i + \beta_{12} CONSUMPTION\_STORAGE\_PERIOD_i + \beta_{13} ESTORAGE\_PERIOD_i + \beta_{14} STORAGE\_PLACE_i + \beta_{15} MAIZE\_PROTECTANT_i + \beta_{16} INSECT_i + \beta_{17} SHELLED\_MAIZE_i + \beta_{18} REGION_i + \mu_i$$

Description of the variables in equation 1 is in Table 1.

Variable	Description of variables for grain maize farmers	Unit	A priori signs
MAIZE_PHL (Dependent variable)	Maize post-harvest loss		
GENDER	Sex of farmer: 1=Male, 0=Female	Dummy	±
AGE	Age of Household head in years	Years	±
FAMILY_SIZE	Number of people living in household	Number	±
CREDIT	Farmer obtained credit: 1=Yes, 0=Otherwise	Dummy	±
BICYCLE_ OWNERSHIP	Ownership of bicycle/ bike	Dummy	±
MAIZE_VARIETY	Type of maize: 1=, Local maize, 0=Improved maize	Dummy	±
STORE_ COWPEA2014	Farmer stored Cowpea in 2014: 1=Yes, 0=Otherwise	Dummy	±
MAIZE_DRYING_PERIOD	Period farmer dried maize before storage in days	Days	±
STORAGE_ DECISION	Household member who took decision to store maize: 1=Male, 0=Otherwise	Dummy	±
PICS_ USAGE	Farmer stored with PICS: 1=Adopt PICS, 0=Otherwise	Dummy	±
EXPECTED_ STORAGE_ PERIOD	Expected Storage period in months	Months	±
SALES_ STORAGE_ PERIOD	Actual storage period before sales in months	Months	±
CONSUMPTION_STORAGE_PERIOD	Actual storage period before consumption in months	Months	±
STORAGE_ PLACE	Place maize was stored: 1=Inside house, 0=Warehouse	Dummy	±
MAIZE_PROTECTANT	Used insecticide: 1=Yes, 0=Otherwise	Dummy	±
INSECT	Major source of loss: 1=insect as major source of loss, 0=Otherwise	Dummy	±
SHELLED_ MAIZE	State in which maize is stored: 1=Maize is shelled for storage, 0=Not-shelled	Dummy	±
REGION	Region/zone where the farmer comes from: 1 = Northern Region, 0= Southern Region of Nigeria	Dummy	±

Table 1: Description of key variables on factors influencing probability and intensity of PHL of maize grains.

Logit model

The data collected included the decision of the farmers to use PICS bags or not use for storage. Those who took decision to store maize grains with PICS bag were scored '1', while those who did not store their maize grains with PICS bag were scored '0'. The empirical model employed for the decision to store or not to store maize grains with PICS bag after harvest was Logit model. The variables described in Table 2 were those used as determinants for decision to store or not to store the grains in PICS bag.

Variable	Description of variables for grain maize farmers	Unit	Apriori signs
PICS_ONLY (dependent variable)	Farmer stored with PICS only: 1=Yes, 0=otherwise	Dummy	
FARM_EXPERIENCE	Farm experience of the farmers	Years	+
STORE_COWPEA2014	Farmer stored Cowpea: 1=Yes, 0=Otherwise	Dummy	+
PICS_AWARENESS	Awareness of hermetic storage: 1=Yes, 0= Otherwise	Dummy	+
MAIZE_STORAGE_PERIOD	Storage period in months	Months	+
MAIZE_QTY_CONSUMED	Quantity of maize consumed	Kg	-
INSECT	Major source of loss: 1=insect as major source of loss, 0=Otherwise	Dummy	+
MAIZE_VARIETY	Type of maize: 1=Local maize, 0=Improved maize	Dummy	±
ASSOCIATION_MEMBERSHIP	Membership of association: 1=Yes, 0=Otherwise	Dummy	±
SAVING	Amount of money saved by the farmer	Naira	+
MAIZE_PHL	Quantity of maize lost at post-harvest	%	-

Table 2: Description of key variables on decision to store maize grains using PICS bag.

$$Y_i(PICS\_ONLY) = \beta_0 + \beta_1 FARM\_EXPERIENCE_i + \beta_2 STORE\_COWPEA_i + \beta_3 PICS\_AWARENESS_i + \beta_4 MAIZE\_STORAGE\_PERIOD_i + \beta_5 MAIZE\_QTY\_CONSUMED_i + \beta_6 INSECT_i + \beta_7 MAIZE\_VARIETY_i + \beta_8 ASSOCIATING\_MEMBERSHIP_i + \beta_9 SAVING_i + \beta_{10} PHL\_OPV_i + \mu_i$$

The explanatory/independent variables included farmer, farm and institutional factors postulated to influence storage decision of farmers. These variables with their a priori signs are listed in Table 2 for Logit model. The rationale for inclusion of these factors was based on previous agricultural literature on grain storage and the analysis of these systems.

Gender (GENDER): While it has been indicated from literature that gender is an important variable which affects PHL, Babalola., *et al*, [34] believe that gender has no effect on PHL. Some studies however are of the opinion that female farmers were prone to high levels of losses than their male counterparts and that male farmers tended to experience less loss than females [35,36]. A study in Malawi [37]. reported that post-harvest loss affected female headed households more because they were deemed to be too slow to buy and apply actellic (a protectant) Lusiba et al [38]. shed a different light on it and discovered that males increased PHL when they were hired as labour by female-headed households; there was more PHL because the labour was accessed late and there was no effective supervision due to cultural restraints.

Age (AGE_Househead): Abdul-Fatahi., *et al* [39]. Reported in his work that there is no significant relationship between age of respondent and quantity of loss. There was a completely different opinion from Ansah and Tetteh, [40] who argued that there was a negative coefficient on age which indicated that older people were not as effective as youthful farmers and did not have the ability to effectively manage postharvest losses; he argued his position that at younger ages, farmers had more strength and zeal for more effective management strategies that reduced postharvest losses.

The number of members of the household (FAMILY_SIZE): Available literature agrees that the larger the household size, the more the ability to manage postharvest losses effectively compared to smaller sized households [35,39,40] the argument is that relatively high amount of family labour are more readily available and are at the disposal of the farmer for harvesting and other processes for speed and efficiency, ceteris paribus and thereby record lower levels of post-harvest loss. It is unlike the smaller sized households where the scarcity of hands will reduce the speed and efficiency with which post-harvest activities can be carried out, thereby leading to high post-harvest losses. It means then that large family size is negatively correlated to PHL.

Farmer obtained credit (CREDIT): Kadjo., *et al* [41]. reports that farmers were limited in strategies to cope with storage (post-harvest) losses because of credit constraints, including high cost of capital; McNamara and Tata [42], were of the opinion that credit facilities will enable smallholder farmers to be able to acquire low cost post-harvest technologies. A study conducted in Tanzania reports that farmers may not be able to afford post-harvest technologies up front and may require credit to pay for post-harvest storage technologies; traders and farmer organizations on the other hand would also like financing for hermetic cocoons [43]. The implication is that non-access to credit will be a major barrier to reducing food loss [44] while access will control post-harvest losses.

Ownership of bicycle (BICYCLE_OWNERSHIP): Transportation of farm produce done by bicycles might have significant contribution to post-harvest losses; losses have been recorded to have occurred during transportation of crops by bicycle and other means to the tune of 2.5% [45,46]. In SSA, there is relatively little access to intermediate means of transport such as bicycles, handcarts, animal-drawn carts, or motorcycles [47]. As reported by World Bank [48] smallholders move grains using head load; bicycle; animal-drawn carts; tractors; trailers; pickups and taxis, depending on the available transport and quantity of grain transported; these modes of transport lead to high PHL, as the grain is not properly protected from exposure to the elements, insects, birds, and theft. In the study by Ategeka [49] it was reported that some farmers did not transport their maize immediately from the garden to the storage facilities and this increased risk of pest attack and theft. This may pre-suppose that the farmers maybe did not own any form of mobility thus leading to PHL.

Type of maize variety (MAIZE_VARIETY): Extent of loss depends on maize varieties as large weight loss differences occur between hybrid and local/improved varieties, but most varieties are susceptible [35,37,50] added that cultivation of improved varieties was associated with lower levels of losses as they had certain advantageous qualities that the local varieties did not have [37]. However, had a somewhat different opinion that most hybrids were prone to weevil and other insect's attacks and that local maize and composite [open pollinated varieties (OPVs) of maize] were relatively more resistant to pest attacks than hybrids were. Explaining further, World Bank [47] said that high-yielding varieties often had greater susceptibility to pest attacks post-harvest, due to softer, more easily eaten grain. There does not seem to be an agreement from literature on the expected a priori sign with maize variety type and PHL. Adopting PICS bag is expected to reduce PHL for maize grains generally; extent of such reduction may depend on the varieties to be stored.

Storing of cowpea in the year of survey (STORE_COWPEA2014): The rationale for including this variable was premised on the fact that most of the farmers interviewed also produced cowpea especially in the Northern Nigeria. There, cowpea is more susceptible to insect attack compare to maize grain; priority is given to cowpea storage than maize storage. In addition, previous survey had been conducted on cowpea storage where cowpea's farmers were encouraged to use PICS bag (a hermetic storage technique) since 2009. There is possibility that a grain farmer who has been using this technique will be challenged to try it for maize grain, that is storing of cowpea can influence storage of maize grain by farmers producing both, thus reducing PHL and encouraging farmers to adopt PICS bag.

Period of drying before storage (MAIZE_DRYING_PERIOD): Maize gets lost during the drying phase through over-dried cobs [51] and during the drying process itself [52], Kumar and Kalita [53]. However, supported drying, reporting that it was a critical step after harvesting to minimize storage losses but that if not done adequately could result in significantly high losses during storage. World Bank [47] also added that grains had to be dried in such a manner that damage to the grain was minimized and moisture levels were lower than those required to support mould growth during storage (usually below 13-15 percent). The connotation for that is that those who skip the drying process will at least not have to lose maize during that phase but that those who dry properly will not have to suffer losses either. World Bank [47] argued further that successful drying alone was not a remedy against all PHL, as insects, rodents, and birds may invade drying cribs or stores after harvest. Wikipedia [10] cited Harris and Carl [54] as saying that most grains should ideally be dried to acceptable levels within 2 - 3 days of harvest.

Using PICS bag for storage of maize (PICS_USAGE): PICS bag storage is sustainable, cost effective, user-friendly and environmentally benign and its use has resulted in up to a 98% reduction in storage losses, maintained seed viability and quality for long storage times [53,56]. In their report, Tefera., *et al* [47,57]. State that even during long distance (international) shipments, hermetic storage had been observed to be very effective in avoiding the losses (storage losses less than 1%). Bakoye., *et al.* [58] suggested that low-cost PICS bags and other hermetic technologies were among the numerous technologies available that provided effective and economical control of insects, stating categorically that maize could be safely stored in hermetic containers such as PICS bags. Corroborating the above, Baoua., *et al*. [59] observed that after 6.5 months of storage using PICS bags, there was 95 - 100% insect mortality and seed viability was well maintained while Tefera., *et al.* [60] [48] argued that traditional grain storage facilities may not offer protection against large grain borer (LGB); Costa [61], estimated losses as high as 59.48% in maize grains after storing them for 90 days in the traditional storage structures (granary/polypropylene bags). Although these hermetic bags cost significantly more than the traditional woven bags, the need for chemicals, pesticides and insecticide applications is eliminated [53,62]. It is apparent from literature that PICS usage is negatively correlated with PHL.

Storage period either expected (EXPECTED_STORAGE_PERIOD): During storage for sales (SALES_STORAGE_PERIOD) or consumption (CONSUMPTION_STORAGE_PERIOD) accounted for the maximum fraction of all postharvest losses for cereals in developing countries according to Kumar and Kalita [53]. In the study of Bakoye., *et al.* [58] wholesalers were observed to have higher densities of insect in their stores; retailers had 16 times reduced infestations while producers had zero incidence. The argument provided was that wholesalers bought grain from several farmers (some of which already had low infestations) and held it for several months; storage allowed the insects to reproduce over multiple generations. This pre-supposes then that storing of maize will increase post-harvest loss. In a study conducted in Tanzania, Rugumamu [51] reported that the fourth phase of post-harvest processes of maize is storage-based where grains were stored for later use, though sporadic rains were reported by Nzioki and Kandiwa [52], to occur and destroy maize both at the farm and in storage; this implies that maize stored by farmers for future use are open to losses and that the longer it was stored, the more the PHL. However, the use of hermetic storage like PICS bag is expected to reduce such losses.

Place of storage (STORAGE_PLACE): Farmers widely store their grains inside the house and in their bedrooms (though the women would rather not store in their bedrooms because they believe that the practice of dusting the maize with super- actellic is hazardous to their health); storing inside the house is done as a result of theft which is a major threat to farmers and as a liquid savings mechanism [37,52,63]. Some others store their maize seeds by hanging the unopened cobs under the kitchen roof over the fire place to prevent attacks by weevils and other pests thereby preserving for the next planting [52,53]. Still, for those who belong to associations, they typically store some portion of their grain at home and some portion in the group's warehouse [63]. However, Samuel., *et al.* [64] opined that bulk storage facilities and warehouses (classified as poor storage structures) cause losses in maize. One may draw from the fore-going that whether one is storing inside the house or at the warehouse, as Babalola., *et al*. [34], submitted, poor storage facilities bring about increase in losses.

Using protectant (MAIZE_PROTECTANT): It would appear from literature that the use of protectant is a control measure against post-harvest losses and is negatively correlated with post-harvest losses. As observed, the addition and dusting of maize with insecticides and spraying of pests with pesticides and herbicides controls and limits loss due to large grain borer (LGB), weevils and pests [37,50,52]. One farmer in a study in Kenya reportedly used herbs to clean the store before storing maize in it [52] in order to reduce PHL. Despite its effectiveness in controlling PHL, farmers have become more aware of the potential health issues associated with insecticides, especially when the grain is stored within the home [62]. Even women reported that the practice of storing grain within their bedrooms is hazardous to their health because the maize is dusted with super- actellic [52].

Insect (INSECT): Higher density of insects in stores leads to higher losses [58]. Insects and particularly weevils and LGB with some other named factors have been reported as constituting a source of post-harvest loss [52]. According to Kumar and Kalita [53], they are a major cause of losses during storage. Insects played a role (14.7%) in post-harvest loss of cereals after rodents/pests (41.5%) and rotting (14.9%). Oguntade [65] Maliro and Kandiwa

[37]. Kumar and Kalita [53] and Lane and Woloshuk [62]. believe that insects (weevils and LGB) are a major source of loss, including dry matter loss with LGB causing [60] high grain damage and weight loss. To further corroborate the fact about insects, Abass., *et al.* [45], reported that after six months of maize storage, LGB was responsible for more than half (56.7%) of the storage losses, followed by losses due to grain weevil.

To underscore the critical role that insects play in PHL, World Bank [47] reported that LGB infestation, if left unchecked, may result in the total destruction of the stored grain. On the other hand, adopting PICS bag will reduce PHL due to insect infestation, as it is capable of depleting air meant for insect respiration thus gradually eliminating such insect in storage.

Shelling maize for storage (SHELLED_MAIZE): While Hodges and Maritime [50], submitted that shelling grain is a standard recommendation to limit LGB losses, Nzioki and Kandiwa [52]. Reported that smallholder farmers stored their unopened cobs by hanging under the kitchen roof over the fire place to prevent attacks by weevils and other pests. World Bank [47] did not treat shelled maize differently from unshelled but reported that as grain or cobs (without LGB infestation), maize typically underwent 4 - 5 percent losses in storage. This implies that both shelling or non-shelling of maize may have a negative correlation with post-harvest loss.

The number of months of storing maize (MAIZE_STORAGE_PERIOD): The expected sign for the storage duration coefficient is positive as very little loss occurs during the initial periods of storage [40,50]. This denotes that the longer maize is stored, the better the post-harvest techniques that must be employed to avoid losses, implying that longer storage periods translate to higher postharvest losses.

REGION (REGION): The geographical location of the study state (REGION) can also influence the PHL of maize. The population and state of development of supporting institutions of a particular state or region or area could favor PHL [66]. Kc., *et al.* [67] implied in their work that post-harvest loss was location specific explaining that causes of loss vary between the Global North (where food waste happened predominantly at the consumer and retail end of the food chain), and the Global South (where food waste was mostly a function of poor storage and marketing infrastructure). Postharvest loss (PHL) in storage varies widely with climate [47]. This denotes that PHL will vary from one climate to another.

Farm experience (FARM_EXPERIENCE): There is the tendency for farmers with more experience to have lower levels of postharvest losses as opposed to those with lesser years of experience as such farmers will adopt better storage techniques to curb PHL. The argument is that with more years, farmers seem to be good in making sound decisions in managing their farm operations and handling harvests and pest infestations, hence the less the postharvest loss while low years of experience might be responsible for lack of knowledge and the unavailability of technology of preservation among farmers [36,68,69]. More years of farm experience is thus expected to have a negative correlation with PHL and positive relationship with the use of PICS bag.

Awareness of PICS bag (PICS_AWARENESS): Beale and Bolen [70], were among the first to synthesize research that suggested awareness was the critical first stage of the agricultural technology diffusion process. The awareness stage was hypothesized to be followed over time, by the interest, evaluation, trial and, finally the adoption stages. They defined awareness as the stage where an individual learns of the existence of a technology or practice but has little knowledge about it. Most individual were taught to become aware of new ideas through the mass communications media. Other research has suggested that awareness and the formation of attitudes, is further influenced by agricultural producers' socioeconomic characteristics [71,72]. Awareness is the first step in the consumer adoption process [73]. Decision-makers need to know about a product before they can do anything with it. More information about PICS bag needs to be disseminated to the maize producers, consumers and traders in the value chain.

Quantity of grain consumed (MAIZE_QTY_CONSUMED): On the matter of quantity consumed, Conteh., *et al.* [74] opines that producers use storage technologies that ensure sufficient grain availability for internal consumption during off-season periods. Belonging to a group or association (ASSOCIATION MEMBERSHIP): Farmers' involvement in social activities was measured by membership in social organizations, membership was expected to positively influence adoption because belonging to a social organization provides a platform for spread of information about innovations and willingness to adopt such innovations [75,78]. This can encourage the adoption of PICS bag for storage. In addition, being a member of an association affords a farmer some form of assistance in linking with traders who buy produce after harvesting and invariably have lower PHL and reduced demand for storage technique like PICS bag [34-36]. SAVING: Farmers with 'savings are capacitated to acquire new technologies or innovations. At harvest such farmers can easily afford PICS bag for maize/grains storage; selling the grains at a latter off season period for better price. Postharvest losses in maize production (MAIZE_PHL): The general consensus is that maize stored hermetically (HERMETIC_AWARENESS) in metal silos is expected to keep longer than traditionally stored maize [76].

Results

The cereal considered is maize grains. The total number of households that stored the grains was 1652 including 41(2.5%) that used PICS bags (PICS), 43 (2.6%) for Airtight Container (AC) that are hermetic storage techniques and 256 (15.5%) for Traditional Granaries (TG), 10 (0.6%) for Improved Granary (IG), 1265 (76.6%) for woven bag (WB), and 37 (2.2%) miscellaneous storage methods (OTHERS) that is non-hermetic in nature. Storage type for maize is illustrated in Figure 2. The description of the socioeconomic characteristics of the sampled households in Nigeria by comparing users and non-users of PICS bag technology is presented in section 3.1; storage based socio-economic characteristics of respondents is in section 3.2; post-harvest characteristics of maize farmers is in section 3.3; benefits of using hermetic storage (PICS bag) in section 3.4; the econometric results of the determinants of post-harvest loss (PHL) and determinants of adopting PICS bag technique are presented in sections 3.5 and 3.6 respectively.

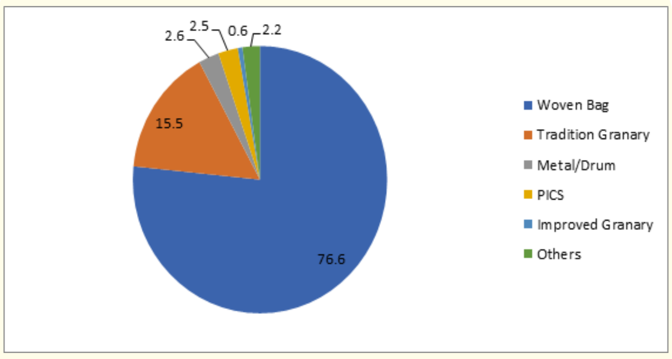

Figure 2: Storage types.

Socioeconomic characteristics of respondents

The general socioeconomic characteristics of the maize grain farmers are given below in Table 3; key factors such as gender, education status, years of living in the community, farming experience, mobile phone ownership, radio ownership, tractor ownership, credit amount in naira owned by farmers and distance to the nearest market were found to be significantly difference between PICS and Non-PICS storage users.

VARIABLE	PICS	Non-PICS	t-test value
Gender of household head (1/0)	1	0.97	6.48***
Education of household head (1/0)	0.51	0.74	-2.92***
Period living in the village (years)	45.08	36.16	3.63***
Age of the head (years)	48.03	45.33	1.37
Household size (number)	9.54	8.99	0.69
Farming experience	23.73	19.61	2.23**
Total farm under cultivation (Farm size) (hectares)	3.13	3.58	-0.87
Ownership of mobile phone (1/0)	0.51	0.76	-3.07***
Radio ownership (1/0)	1	0.9	13.2***
Metal as housing roof material (1/0)	0.88	0.80	1.35
Bicycle, bike & vehicles(Mobility)	0.78	0.75	0.42
Ownership of tractor, or drought animal (1/0)	0.58	0.31	3.29***
Credit amount (Naira)	25000	87927.93	-3.64***
Association membership (years)	13.29	11.22	0.6
Distance in kilometre (nearest market)	10.7(11)	5.1(8.2)	3.14***

Table 3: Socio-economic characteristics of users and non-users of PICS bags (sample mean).

Source: Estimated from PICS Survey Data, 2015. NB: (1/0) Refers to Dummy Variable; ***, **, * Denote Significance at the 1%, 5% & 10% Probability Levels Respectively.

All the households that made use of PICS bags were male-headed while the Non-PICS using ones had 97% of the heads as males, this was significant at 1%; this implies that there should be an all-inclusive strategy for women in the sensitization on PICS bags. The PICS using households had about half of the heads educated (51%) while those of Non-PICS had a large proportion (74%) educated, this was significant at 1%; this shows that the more educated household heads are, the more sceptical they are about adopting PICS bags. On the basis of length of time of having lived in the village, those who have adopted PICS bags have lived there longer (approximately 48 years) than those who have not adopted (approximately 36 years); this is significant at 1%; their having lived in the village for a longer period may pre-dispose them to adopting PICS bags on the basis that the bag may be more attractive to them because they have not for a long time been exposed to a new technology. The mean age of household heads PICS bags adopters and non-adopters is 48 and 45 years respectively; the older heads might have adopted the bags more because it is a totally novel innovation unlike other ones they had seen when they were younger, and which might have failed. Household size of PICS bags adopters and non-adopters is about the same (ten and nine respectively); this almost does not make any difference in adopting or not adopting the bag. PICS-using households had longer experience in farming (about 24 years) than their counterparts (about 20 years); this is closely in line with them adopting because for the longer length of time for which they had farmed, this innovation was completely different in its simplicity, thereby making it attractive. It is significant at 5%.

Non-PICS using households had larger land area for planting (approximately 4 ha) as opposed to the other group (approximately 3 ha); the implication of this is that those with the smaller land holding have decided to guard and protect the output from their farm and not allow any waste by using PICS bags as opposed to the other group who may still afford to lose some maize since their larger land would have yielded more (ceteris paribus). More of Non-PICS using households used mobile phones (76%) compared to their counterparts (51%); this was significant at 1%. All of the PICS users owned radios (100%) while nine out of ten (90%) of the non-users owned radio; however how marginal this may be, it implies that through the ownership of radios, the PICS users were possibly more exposed to adoption-inducing information on the bag than the Non- PICS users. This was significant at 1%. Approximately nine out of ten (88%) of PICS users had metal as roof material as opposed to their counterparts where eight out of ten (80%) had metal roof material; this may imply that the PICS users were possibly used to the finer things of life and this will pre-dispose them better to adopt a fine technology like PICS bag. There is a marginal difference in mobility between users of PICS (78%) and non-users (75%); it will appear then as though mobility will pre-dispose the users to go any distance and purchase PICS bags where available. Approximately double of PICS bags non-adopter's own tractors or draught animals; 58% of adopters and about 31% of non-adopters own tractors or draught animals; the implication is that adopters would appear to be more capital-intensive in their production than non-adopters; this is significant at 1%.

Non- PICS-using households had borrowed credit to the tune of N87927.93 as against N25000.00 for their counterparts; it is significant at 1%. This may imply that the PICS-using households were wealthier and had more resources at their disposal through the use of the bag and did not require more credit than N25000.00 while their counterparts who were not using the bag had lost some maize, had not realized large revenues and therefore needed to borrow credit. PICS-users had spent longer time belonging to associations (about 13 years) than the Non-users (11 years); that is probably why they adopted the bag due to exposure and information through networking. For PICS-using households, the distance travelled to the nearest market (10.7 km) is twice than travelled by non-PICS-using households (5.1 km) with a significance of 1%; this connotes that in travelling out of town to that long distance, the users had been better exposed, and their thinking broadened to accept the technology unlike their counterparts who only had to travel 5.1 km to the nearest market and whose exposure might be quite poor. Therefore, it is expected that the imbalance in socioeconomic variables would affect choice of the farmers to store or not to store their grain maize in the PICS bag after harvest in this study.

Storage based and post-harvest socio-economic characteristics of respondents

Table 4 shows storage based socioeconomic characteristics of the maize farmers; variables such as hermetic storage awareness, adoption of hermetic storage, household decision maker in choosing storage technology, maize type stored, total quantity of maize stored, quantity of maize stored for consumption, place of storage for maize grain and drying period on field before harvesting are variables that are significantly different between users and non-user of PICS bags (PICS). PICS users were all aware of and ever adopted hermetic storage technique, while only 29% were aware of it and 14% ever used it among Non-PICS users. Non-PICS were more experienced in usage of their storage methods than PICS-users, years of experience for Non-PICS for using their choice storage methods was 8.43 compared to 5.24 for PICS. All male members of PICS family made decision on choice of storage techniques; while 91% did so for Non-PICS family. Local maize was mainly stored by the respondents compared to improved ones; 78% of PICS users stored local maize compared to 64% for Non-PICS. Total maize grain stored including one for sales and consumption was higher for PICS users; in regard to total grain stored, on average 2157.32 kg was stored in PICS while 1630.58 kg was stored in Non-PICS and the difference was significant at 10% level of probability. Non-PICS users preferred storing grains at home compare to warehouse, percentage that stored at home was 84% for Non-PICS users and 73% for PICS users. On the other hands, it meant that PICS users adopted more of warehouses in storing their grain than Non-PICS users, however the percentage that did that need to be improved upon. An average PICS user dried his maize on field for longer period (49 days) than for a Non-PICS user (38 days). Differences in these variables were statistically significant. The simple comparison of the two groups of farmers suggests that PICS users and Non-PICS users differ significantly in some proxies of human, social and physical capital. The difference would likely affect choice of the farmers types of storage techniques for storing their grain maize after harvest in this study.

VARIABLE	PICS	Non-PICS	t-test value
Awareness of hermetic storage (1/0)	1	0.29	10***
Ever used hermetic storage (1/0)	1	0.14	99.59***
Experience in using chosen storage technology (years)	5.24	8.43	-8.37***
Decision maker to adopt storage technology (1/0)	1	0.91	12.72***
Maize type (local /improved) (1/0)	0.78	0.64	2.06**
Total maize grain stored (kilogram)	2157.32	1630.58	1.78*
Quantity of maize stored for sale(kilogram)	1207.32	931.49	0.99
Quantity of maize stored for con sumption (kilogram)	950	700.14	1.75*
Place of storage (inside house/warehouse) 1/0	0.73	0.84	-.84*
Drying period on field before harvesting (days)	49	38	2.59**
Drying period for cob grains before final storage (days)	21.70	18.49	1.49
Drying period for shelled grains before final storage (days)	10.45	9.56	0.39
Storage of cowpea (cowpea/another legume) 1/0	0.44	0.34	1.21

Table 4: Storage based socio-economic characteristics of users and non-users of PICS bags (sample mean).

Post-harvest characteristics of maize farmers

Farmers under study stored grains for different reasons: 33.5% stored for consumption only, 4.5% stored for 'sales' only and 61% stored for both consumption and sales, while 1% stored for other purposes which can be for seeds for example. Based on this fact, reliable storage techniques need to be identified and recommended so that PHL can be reduce to barely minimum level or else it will have negative and severe effects on households' income and living standard of the farmers.

In comparing the storage types (PICS and Non-PICS) in Table 5, the following variables were considered: Actual storage period before sales - SALES_STORAGE_PERIOD, Grain lost in storage, kg - GLOST, Post-Harvest Loss - MAIZE_PHL, losses due to insect pest insect as the most important source of loss - INSECT and form of storing maize grain (shelled or unshelled) (1/0)- SHELLED_MAIZE. This paper emphasis on variables that were found significant: MAIZE_PROTECTANT, GLOST, INSECT AND SHELLED_MAIZE. In case of MAIZE_PROTECTANT, 37% of Non-PICS group applied insect protectant to their maize grains, while PICS group did not, the quantity of grains lost in storage, GLOST was smaller for PICS (1.54 kg) and bigger for Non-PICS (41.2 kg) and was significant ($p < 0.001$). The MAIZE_PHL for PICS was 0.12% compared to 4.47 for Non-PICS and the difference was significant at 1% probability level to the favour of PICS users. Insect as an important source of storage loss (INSECT) was considered, the result showed that 15% of PICS users had losses through insect attack compared to 70% for Non-PICS, and the difference was significant ($p < 0.001$). Table 5 shows that all PICS users shelled their maize under storage while 92% did same for Non-PICS, the difference between the two groups was significant ($p < 0.001$).

VARIABLE	Pooled	PICS	NON-PICS	t-test value	P<t (sig)
Storage Period_ grain for sales SALES_STORAGE_PERIOD	3.29	3.54	3.28	0.43	.670
Storage Period_ grain for consumption CONSUMPTION_STORAGE_PERIOD	7.75	8.98	7.71	1.55	.129
Applied insect protectant (1/0) MAIZE_PROTECTANT	0.36	0.00	0.37	-30.79***	.000
Maize lost in storage, Kg GLOST	40.19	1.54	41.20	-10.93***	.000
Post-harvest loss (lost/totaL grain stored*100) MAIZE_PHL	4.40	0.12	4.47	-19.36***	.000
Insect as the most important source of loss (1 /0) - INSECT	0.68	0.15	0.70	-9.64***	.000
Form of storing maize grain (shelled or unshelled) (1/0)- SHELLED_MAIZE	0.92	1.00	0.92	11.50***	.000

Table 5: Post-harvest characteristic of grain maize farmers.

Source: Estimated from PICS Survey Data, 2015. NB: 1. Storage Period is in 'Months';

Additional analysis was done in Table 6 using Analysis of Variance test (ANOVA), to be more specific and see which storage types are contributing better to grain storage duration, reduction in PHL and thus promoting food security. In Table 6 PICS and NON-PICS storage methods were further divided into hermetic and non-hermetic types. Hermetic type was disaggregated into its component parts of 'Airtight containers (AC) and Purdue Improve Crop Storage (PICS) bag', likewise, Non-Hermetic was divided into its parts of Traditional Granary (TG), Improved Granary (IG), Woven Bag

(WB), and other miscellaneous storage (OTHERS). All the four conspicuous storage types were compared, while OTHERS was drop. Variables that were significant and need to be noted include: CONSUMPTION_STORAGE_PERIOD, MAIZE_PROTECTANT, MAIZE_PHL, INSECT and SHELLED_MAIZE. ANOVA shown that there was significant difference in CONSUMPTION_STORAGE_PERIOD ($P < 0.001$), MAIZE_PROTECTANT ($P < 0.001$), MAIZE_PHL ($P < 0.001$), INSECT ($P < 0.001$) and SHELLED ($P<0.001$). Further analysis was done using Least Square Difference (LSD) to further test which of the storage types is superior for each variable, and the result is on Table 7.

Variables	Pooled	Hermetic		Non-Hermetic				F-value	P<F
		PICS	Airtight Container(AC)	Traditional Granary(TG)	Improved Granary (IG)	Woven Bag(WB)	Others (OTHERS)		
Storage Period_ grain for sales APERIOD	3.29	3.54	3.50	3.57	4.20	3.21	3.22	0.88	0.50
Storage Period_grain for consumption CONSUMPTION_ STORAGE_PERIOD	7.75	8.98	6.84	6.53	7.00	8.06	4.89	8.09***	0.00
Applied insect protectant (1 /0) PROTECTANT	0.36	0.00	0.47	0.45	0.30	0.35	0.31	7.00***	0.00
Maize lost in storage, Kg GLOST	40.19	1.54	31.66	58.51	47.50	38.54	18.03	1.80*	0.11
Post-harvest loss (lost/totaL grain stored*100) MAIZE_ PHL	4.40	0.10	3.60	6.60	3.10	4.20	5.75	6.34***	0.00
Insect as the most important source of loss (1 /0) - INSECT	0.68	0.15	0.59	0.71	0.90	0.70	0.73	12.53***	0.00
Form of storing maize grain (shelled or unshelled) (1/0)- SHELLED	0.92	1.00	0.93	0.83	1.00	0.95	0.47	29.63***	0.00

Table 6: Maize-level post-harvest characteristic of grain maize farmers disaggregated by storage types.

Source: Estimated from PICS Survey Data, 2015.

NB: 1. Storage Period is in 'Months'; 2. ***, **, * Denote Significance at the 1%, 5% & 10% Probability Levels Respectively.

VARIABLE (I)	VARIABLE (J)	SALES_ STORAGE _PERIOD	CONSUMPTION _STORAGE _PERIOD	MAIZE_ PROTECTANT	GLOST	MAIZE_ PHL	INSECT	SHELLED_ MAIZE
		Mean Difference (I-J)	Mean Difference (I-J)	Mean Difference (I-J)	Mean Difference (I-J)	Mean Difference (I-J)	Mean Difference (I-J)	Mean Difference (I-J)
PICS	TG	-0.03034	2.44386***	-0.447***	-56.97736***	-6.26789***	-0.563***	0.171***
	IG	-0.66341	1.97561	-0.300*	-45.96341	-3.0084	-0.754***	0.00
	AC	0.03659	2.13415**	-0.465***	-30.12195	-3.29022*	-0.439***	0.073
	WB	0.32426	0.91679	-0.354***	-37.00374*	-3.96190***	-0.549***	0.05
	OTHERS	0.316	4.08303***	-0.306***	-16.49567	-5.62879***	-0.584***	0.533***

Table 7: Least Square Difference for comparisons among different storage types.

Source: Estimated from PICS Survey Data, 2015.

NB: 1. Storage Period is in 'Months'; 2. ***, **, * Denote Significance at the 1%, 5% & 10% Probability Levels Respectively.

Tables 6 and 7 complemented each other to explain the differences in variables among different storage techniques. In Table 6, average storage period for grains meant for (CONSUMPTION_STORAGE_PERIOD) was highest for PICS, and the differences between it and TG, AC and OTHERS in Table 7 was respectively significant. None of the PICS user adopted the use of insect protectant, while other storage techniques used; the difference among storage techniques differed significantly. By following this up in Table 7, users of PICS bag were significantly different from TG ($p < 0.01$), IG ($p < 0.1$), AC ($p < 0.001$), WB ($p < 0.001$) and OTHERS ($p < 0.001$) respectively. The quantity lost (GLOST) in TG and WB was respectively higher than PICS and were statistically significant (Table 7). In case of PHL, only 0.1% was lost in PICS and it was the least among all storage techniques adopted by the farmers; from Table 7, when compared each storage technique to PICS, each was significantly different from PICS except IG. Only 15% of maize's farmers indicated that insect was the most important source of loss of grains in storage while it was 59% for AC, 71% for TG, 90% for IG, 70% for WB and 73% for OTHERS; Table 7 indicates that the difference between PICS and every other storage technique was significantly different at 1% level of probability. Form of storing maize (SHELLED_MAIZE) was a significant variable between PICS and TG ($p < 0.01$), and between PICS and OTHERS ($p < 0.01$), it thus meant that PICS users stored maize grain in shelled form than either TG and OTHERS. The implication is that PICS bag gives opportunity the longest storage period for storage meant for consumption; it also gives the minimum loss of grain during storage and the least PHL, thus enabling farmers to get maximum income from their stored grains. Farmers who store grain may experience significant quantity losses due to damage from insect pest and subsequent price discounts for damaged grain; however, losses through insect was least for PICS (this is further illustrated in Figure 3) and by using PICS bag for storage, the use of insecticide/pesticide may not be necessary as the none of farmers used insecticide with PICS bag.

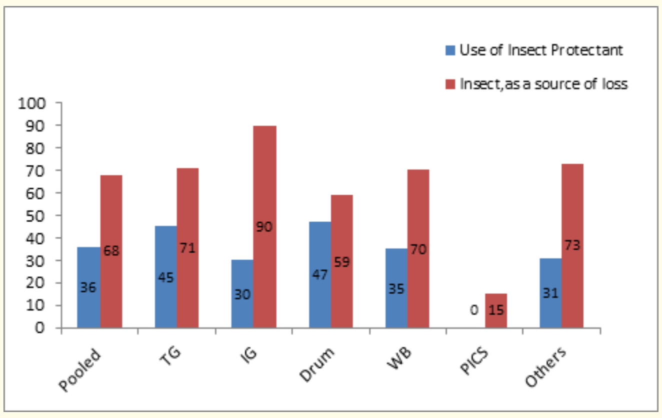

Figure 3: Insect as a major source of PHL & Use of Insect Protectant on Maize Grain.

Benefits of using hermetic storage (PICS bag)

Part of the reasons for not using hermetic storage method as stated in Table 8 included 'being unfamiliar with it (40%, being expensive (26%), and not being accessible/available to farmers (13%)'. According to users of Hermit storage methods in Table 9, the most important benefit derived from the use of Hermetic method of storage was 'Less grain damage for best quality (62.7%) and less grain damage for better price premium (25%)' among others.

Reasons	% Respondents
Expensive	26
Not accessible	13
Unfamiliar	40
Others	21

Table 8: Reasons for not using PICS bag.

Source: Estimated from PICS survey data, 2015.

NB: 1. Storage Period is in 'Months'; 2. ***, **, * Denote Significance at the 1%, 5% & 10% Probability Levels Respectively.

Tobit model results of determinants of PHL

Tobit model not only measured the probability of post-harvest loss of maize grains, but also took care of its intensity of loss. The result of Tobit analysis is shown in Table 10; overall model fit was good since the values of the log likelihood (-3906.35), pseudo R^2, and probability of Chi-square (416.86) were significant ($P < 0.00$). The explanatory variables used in the model were collectively able to explain the farmers' PHL behaviour and the intensity of such behaviour; many of the included variables were significant for determining PHL of farmers and its intensity. Regression result shows that independent variables such as "gender (GENDER), age of household head (AGE), farmers acquiring credit for production (CREDIT), gender responsible for storage decision (STORAGE _DECISION), drying period before storage (MAIZE_DRYING_PERIOD), places where farmers store their maize grains (STORAGE_PLACE), insect attack as a major source of loss(INSECT) and storing of shelled maize(SHELLED_MAIZE) " have the probability and intensity of increasing PHL, while "the use of PICS bag(PICS_USAGE), expected storage period of maize grain (EXPECTED_STORAGE_PERIOD), storage period of maize grain before consumption (CONSUMPTION_ STORAGE_PERIOD), application of protectants/insecticide to maize in storage (MAIZE_PROTECTANT), type of maize variety stored (MAIZE_VARIETY) and ecological location of the farmers (REGION)," have the probability and intensity to reduce PHL.

Reasons	% Respondents
Less grain damage for best quality	41
Consumption	16
Less grain damage for better price premium	15
Cheaper cost of storage	4
Seed	25

Table 9: Most important benefit for using PICS bag.

Source: Estimated from PICS survey data, 2015.

NB: 1. Storage Period is in 'Months'; 2. ***, **, * Denote Significance at the 1%, 5% & 10% Probability Levels Respectively.

PHL_OPV	Coef.	t-value	P > |t|	dy/dx
GENDER (Dummy: Male=1, Female=0)	4.544	2.45	0.014	0.200
AGE (years)	0.038	1.91	0.057	0.002
FAMILY_SIZE (Number)	-0.027	-0.63	0.529	-0.001
CREDIT (Dummy: Yes=1, No=0)	2.899	3.81	0.000	0.123
BICYCLE_OWNERSHIP (Dummy: Yes=1, No=0)	-0.678	-1.22	0.224	-0.030
MAIZE_VARIETY (Dummy: Local maize=1, Improved maize=0)	-0.984	-1.67	0.094	-0.043
STORE_COWPEA2014 (Dummy: Yes=1, No=0)	-0.781	-1.37	0.170	-0.034
MAIZE_DRYING_PERIOD (Days)	0.042	2.09	0.037	0.002
STORAGE _DECISION (Dummy: Male=1, Otherwise=0)	1.757	1.70	0.090	0.078
PICS_USAGE (Dummy: Adopt PICS=1, Otherwise=0)	-6.859	-3.11	0.002	-0.294
EXPECTED_STORAGE_ PERIOD (in months)	-0.276	-2.48	0.013	-0.012
SALES_ STORAGE_PERIOD (in months)	0.047	0.52	0.604	0.002
CONSUMPTION_ STORAGE_PERIOD (in months)	-0.154	-2.10	0.036	-0.007

STORAGE_PLACE (Dummy: Inside house=1, Warehouse=0)	1.726	2.15	0.031	0.077
MAIZE_PROTECTANT (Dummy: Use of protectant, Yes=1, No=0)	-1.241	-2.21	0.027	-0.055
INSECT (Dummy: Major source of loss=1, Otherwise=0)	9.878	15.33	0.000	0.420
SHELLED_MAIZE (Dummy: Maize is shelled for storage=1, Not-shelled=0)	5.678	7.09	0.000	0.250
REGION (Dummy: South=0, North=1)	-2.559	-2.71	0.007	-0.109
Constant	-13.755	-4.24	0.000	
Sigma	8.928			
LR chi2(18)	416.860			
Prob > chi2	0.000			
Log likelihood	-3906.350			
Pseudo R2	0.051			

Table 10: Tobit model results of determinants of PHL in Nigeria, 2014/15.

Explicitly, being a male farmer (GENDER) was positively and significantly associated with PHL (P < 0.05). The marginal effect implicates that being a male farmer will increase PHL of maize grain and its intensity by 20%. Age of farmer was positively and significantly correlated with PHL (P < 0.1); aged farmers have tendency of procuring high PHL than the younger ones. A unit increase in age will increase PHL and its intensity by 0.2%. Access to credit and it acquisition (CREDIT) is expected to empower farmers to afford better technology in storing their grains; however, this study shows that this variable increased PHL and its intensity by 12.3%. The decision on the choice of storage techniques to adopt at home (STORAGE-DECISION) was dominated by men; STORAGE-DECISION was positively and significantly correlated with PHL and its intensity; it increased by 7.8% when men dominated decision makers on choice of storage techniques.

Length of time for drying maize grain before storage (MAIZE_DRYING_PERIOD) was also positively and significantly associated with PHL and its intensity (P < 0.05). The longer the number of days in drying grains, the more the PHL. The marginal effect shows that on average higher number of days for drying will increase PHL and its intensity by 0.2%. Farmer storage of grain inside the home instead of a ware house (STORAGE_PLACE) positively and significantly influence PHL and the extent of the loss (P < 0.05). Storing inside the house of the loss (P < 0.05). Storing inside the house, increased PHL and it's intensity by 7.7%. Insect attack as a major source of loss (INSECT) positively (P < 0.01) increased PHL and the degree of the loss by 42%; this variable is very important for policy deliberation. The form in which maize grain- shelled or unshelled (SHELL) is stored has been found to be a very important determinant of PHL and its intensity; as SHELL was positively and significantly related to PHL (P < 0.01). Marginal effect shows that PHL and its intensity will increase by 25% if maize grain is shelled and stored. Adoption of PICS bag (PICS_USAGE) was negatively and significantly correlated with PHL (P < 0.01), a unit increase in the use of PICS bag will lead to 29.4% reduction in probability of PHL and its intensity in the study area. The shorter the expected period of storage, the lower the probability and the intensity of PHL (P < 0.05) a unit decrease in the expected length of storage (EXPECTED STORAGE _ PERIOD) will reduce probability of PHL by 1.2%. In relation to this, the actual length of storage for grain meant for consumption (CONSUMPTION_STORAGE_PERIOD) negatively and significantly correlated with PHL (P < 0.01), it reduced probability of PHL and its intensity by 0.7%. The use of insect protectant (MAIZE_PROTECTANT) was negatively associated with PHL of maize grain (P < 0.05); its adoption led to 5.5% reduction in probability of PHL and the extent of occurrence. The result shows that the probability of PHL in maize grain was highest with local maize compared to improved ones. Planting of improved maize (MAIZE_VARIETY) reduced PHL and the intensity of the loss by 4.3%. The ecological region (REGION) where maize is majorly cultivated (North) and vice versa (South) differed in their probability and extent of PHL: REGION was negatively correlated with PHL, indicating that southern ecology in Nigeria experienced reduction in PHL than Northern ecology. Moving towards the south would reduce PHL by 10.5%.

Logit model results of determinants of PICS adoption

Determinants of farmers choice to store maize grains using PICS storage method is shown on Table 11; a Logit regression model was estimated using dummy (1,0) for choice status as dependent variable; where '1'is decision to store maize grains using PICS bag storage and '0'is decision to store maize grains using Non-PICS storage method; farmers' socioeconomic characteristics became explanatory variables. Result shows that "years of farm experience (FARM_EXPERIENCE), farmers storing of cowpea (STORE_COWPEA), farmers' awareness of hermetic storage (PICS_AWARENESS) and having financial capital at harvest(SAVING)" influenced positively and significantly, the probability of using PICS bag. On the other hand, 'period of storing grains' (STORAGE_PERIOD), insect as a major source of losses (INSECT), being a member of an association (ASSOCIATION_MEMBERSHIP), and PHL in maize (MAIZE_PHL)" influenced negatively and significantly, the probability of using PICS bag. FARM_EXPERIENCE increased the probability of using PICS bag by 1.0E - 05%; storing of cowpea by farmers increased probability of adopting PICS bag for storing maize grains by 2.27E - 04%; awareness creation on hermetic storage led to 8.33E - 04% increase in the probability of using PICS bag and farmers' financial saving capacity (SAVING) at harvest led to increase adoption of PICS bag by 2.80E - 04%, the use of PICS bag reduced losses through insect (INSECT) by 5.20E - 04%; also an increase in the use of PICS bag reduced PHL (MAIZE_PHL) by 1.30E - 04%. Being a member of an association (ASSOCIATION_MEMBERSHIP) reduced adoption of PICS bag by 1.80E - 04%: an association might not see the benefits of PICS bag yet, thus not encouraging member to adopt it; on the other hands, being a member of an association affords a farmer some form of assistance in linking with traders who buy produce after harvesting and invariably have lower PHL and reduced demand for storage technique like PICS bag [34] and the longer the length of storage period, the lower the adoption of PICS bag; it will reduce probability of adoption by 3.44E - 08%.

Discussion

This study was conducted to examine and understand the effects of PICS bags in reducing post-harvest loss (PHL) on maize storage in Nigeria. Descriptive statistics were used to describe and compute statistics such as mean, SD, frequency distributions and figures. On one hand, the results were used on PHL variables between PICS and NON-PICS technologies; and on the other hand, compare farmers' PHL characteristics among different methods of storage techniques. Econometric modelling also was used to determine factors influencing farmers' PHL, and farmers' decision to adopt PICS bag in storing their maize grains.

Variables	Coef.	z-value	P>|z|	dy/dx
FARM_EXPERIENCE (Years)	0.0536	3.14	0.002	0.00001
STORE_COWPEA (Dummy: Yes=1, No=0)	0.9846	2.3	0.021	0.000227
PICS_AWARENESS (Dummy: Aware=1, Otherwise=0)	2.2976	4.3	0.000	0.000833
STORAGE_PERIOD (In months)	-0.5383	-6.66	0.000	-0.0001
MAIZE_QTY_CONSUMED(Kg)	0.0002	1.1	0.273	3.44E-08
INSECT (Dummy: Insect as a major source of loss=1, Otherwise=0)	-1.7743	-2.98	0.003	-0.00052
MAIZE_VARIETY (Dummy: Local maize=1, Improved maize=0)	-0.1686	-0.33	0.739	-3.3E-05
ASSOCIATION_MEMBERSHIP (Dummy: Yes=1, No=0)	-1.0433	-2.18	0.029	-0.00018
SAVING(Naira)	1.8304	3.08	0.002	0.00028
MAIZE_PHL (%)	-0.6866	-1.99	0.046	-0.00013
Constant	-2.7133	-3.07	0.002	
LR chi2(10)	202.3600			
Prob > chi2	0.0000			
Log likelihood	-88.7300			
Pseudo R2	0.5328			

Table 11: Logit model result of determinants of adoption of PICS bag for maize storage in Nigeria.

Farmers take actions to reduce PHL, either by selling early to avoid losses, applying protectants or use other storage options. The result shows that PICS bag gives opportunity for the longest storage period of 4 months for sales and 9 months for consumption; It also give minimum loss of grain during storage and the least PHL, thus enabling farmers to get maximum income from their stored grains if sold and ensuring longer food security and healthy grains for consumption purpose. Losses through insect was least for PICS bag and by using PICS bag for storage, the use of insecticide/pesticide may not be necessary as there was no farmer that used insecticide with PICS bag in this study. The difference was statistically attested to by t-test.

On GENDER, literature reports it to be one of the important variables which affect losses of maize [1]. In this study, GENDER shows that being a male farmer positively affect PHL, the positive value of the coefficient was in line with the a priori expectation that men headed households incurred more PHL especially when they were hired as labour by female-headed households than women [38]. Close to this is the gender responsible for making storage decision (STORAGE _DECISION), more post-harvest losses were made when males were the main decision makers on storage at homes compared to females. Njiro [55], thought and believed that women are the cornerstone of agricultural production in the rural areas and should make major decisions especially when their husbands were away from home. Base on this paper, storage decision of maize grain is better left to female members of the farm families as gender (GENDER) and making of decision to adopt storage technology (STORAGE _DECISION) were significantly favourable to females than males in reducing PHL. AGE was positively related with PHL, meaning that the older the farmer, the more losses of grains to be incurred; this is supported by Ansah and Tetteh, [40], that argued that older people were not as effective as youthful farmers and did not have the ability to effectively manage postharvest losses; he argued his position that at younger ages, farmers had more strength and zeal for more effective management strategies that reduced postharvest losses.

Maize gets lost during the drying phase through over-dried cobs [51], during the drying process itself [52]. Kumar and Kalita [53], however supported drying, reporting that it was a critical step after harvesting to minimize storage losses but that if not done adequately could result in significantly high losses during storage. World Bank [47] also added that grains had to be dried in such a manner that damage to the grain was minimized and moisture levels were lower than those required to support mould growth during storage (usually below 13 - 15 percent). The result of Tobit model shows that the longer the number of days for drying grains (DRYING_PERIOD), the more grain losses incurred. Wikipedia [10], cited Harris and Carl [54], as saying that most grains should ideally be dried to acceptable levels within 2 - 3 days of harvest, longer drying period will lead to higher PHL. It is the belief of Hodges and Maritime [50] that very little loss occurs during the initial periods of storage (STORAGE_PERIOD), this implies that as storage period grows longer, the higher the postharvest loss. The regression result shows that the shorter the EXPECTED_STORAGE_PERIOD and CONSUMPTION_STORAGE_PERIOD the lower the probability and intensity of PHL. Folayan [1], reports that storage facility is an important variable which affects loss and in regard to places where farmers store grains (STORAGE_PLACE), Babalola., *et al.* [34] opined that whether one is storing inside the house or at the warehouse, as submitted, poor storage facilities bring about increase in losses. Place of storage affect post-harvest loss as poor storage facilities bring about increase in losses [34]. The lack of suitable storage structures or the absence of storage management technologies can cause farmers to sell their farm produce immediately after harvest, so that storing maize is discouraged [74]. STORAGE_PLACE in this paper shows that storing grains inside houses increased probability of PHL as compared to storing in warehouses.

On the use of protectant (MAIZE_PROTECTANT), Hodges and Maritime [50], observed that the addition of insecticide limits loss due to large grain borer (LGB); this is in support of result of Tobit analysis in this paper. Despite its effectiveness in controlling PHL, farmers have become more aware of the potential health issues associated with insecticides, especially when the grain is stored within the home [62]. Even women reported that the practice of storing grain within their bedrooms is hazardous to their health because the maize is dusted with super- actellic [52]. Insect as a major source of attack on grains (INSECT) was highly correlated with PHL, this is in line with Bakoye., *et al.* [58] who stated that insects in stores lead to higher losses. Insects and particularly weevils and LGB with some other named factors have been reported as constituting a source of post-harvest loss [52], according to Kumar and Kalita [53], they are a major cause of losses during storage. To further corroborate the fact about insects, Abass., *et al.* [45], reported that after six months of maize storage, LGB was responsible for more than half (56.7%) of the storage losses, followed by losses due to grain weevil. To underscore the critical role that insects play in PHL, World Bank [47], reported that LGB infestation, if left unchecked, may result in the destruction of the stored grain. In this paper, storing of shelled maize grains (SHELLED_MAIZE) is associated with higher PHL compared to non-shelled ones. World Bank [47] did not treat shelled maize differently from unshelled but reported that as grain or cobs maize typically underwent 4 - 5 percent losses in storage. This implies that both shelling or un-shelling of maize may have a negative correlation with post-harvest loss. McNamara and Tata [42] were of the opinion that credit facilities will enable smallholder farmers to be able to acquire low cost post-harvest technologies; however, the result shows that CREDIT was positively related to PHL, this is against a priori expectation.

Farmers that acquired credit seemed to spend it elsewhere instead of using it to procure better storage techniques that can reduce PHL. Large weight loss differences occur between hybrid/improved and local varieties (MAIZE_VARIETY) as submitted by Hodges and Maritime [50], in line with that reasoning, Aidoo., *et al.* [35] added that cultivation of improved varieties was associated with lower levels of losses as they had certain advantageous qualities that the local varieties did not have. Farmers are more likely to cultivate hybrid/improved grains (MAIZE_VARIETY) that are suitable for preservation and storage as reported by Conteh., *et al* [74]. Large household size (FAMILY_SIZE) translates to lower levels of post-harvest loss because of relatively high amount of family labour for processing to be faster and efficient ceteris paribus [35]. However, this is not significant in this study. As regards BICYCLE_OWNERSHIP, unreliable means of transportation increases PHL as reported by Aidoo., *et al* [35] the result is not significant in this paper. In regard to REGION, Tyler [79] reports that the economic importance of the factors leading to high post-harvest losses varies from circumstance to circumstance under which commodities are grown, harvested, stored, processed and marketed.

On the factors influencing the choice of PICS bag for storing maize by farmers, the general consensus is that maize stored hermetically (PICS bag) is expected to keep longer than traditionally stored maize. FARM_EXPERIENCE increased the probability of using PICS bag by 1.0E-05%; Farmers with more experience (FARM_EXPERIENCE), tend to adopt PICS bag since they understand better devastating effect of insects on stored grains; this will on the other hand help lower levels of postharvest losses [36], as farmers with more years of experience seem to be good in managing their farm and handling harvests [36,35,77]. Storing of cowpea by farmers increased probability of adopting PICS bag for storing maize grains by 2.27E - 04%. PICS bag was first invented for storing cowpea; farmers that had been using it before for storing cowpea (STORE_COWPEA) find it easier to adapt it for storing maize grain.

Awareness creation on hermetic storage (PICS_AWARENESS) led to 8.33E-04% increase in the probability of using PICS bag, as stated earlier under ‘Empirical model’, awareness must precede adoption; farmers that heard and knew about PICS bag were the one that adopted it. Farmers’ financial saving capacity(SAVINGS) at harvest led to increase adoption of PICS bag by 2.80E - 04%, Farmers that had savings at harvest time find it easier to acquire and adopt PICS bag as seen from the result. The use of PICS bag reduced losses through insect (INSECT) by 5.20E - 04%; adoption of PICS bag discouraged or reduced losses due to insect attack thereby reducing maize post-harvest losses. Also, an increase in the use of PICS bag reduced PHL by 1.30E - 04%. PICs bag is expected to store for a minimum of 1 year by design; the bag is made of polythene, farmers that were able to use the bag without perforation on the bag were able to use it for 2 or 3 years. Farmers with longer storage period (STORAGE_PERIOD) intension may not use PICS bag, such farmers may turn to the use of chemical protectants which may be injurious to health of consumers of grain. The result shows that farmers with long storage intention did not adopt PICS bag. The longer the length of storage period, the lower the adoption of PICS bag; it will reduce probability of adoption by 3.44E - 08%. Being a member of an association (ASSOCIATION_MEMBERSHIP) reduced adoption of PICS bag by 1.80E - 04%: an association might not see the benefits of PICS bag yet, thus not encouraging member to adopt it; on the other hands, being a member of an association affords a farmer some form of assistance in linking with traders who buy produce after harvesting and invariably have lower PHL and reduced demand for storage technique like PICS bag [34], in other words, use of PICS bag is also discouraged where storage for sales at off-season is discouraged especially where a group or association arrange market for the members to sell immediately after harvest [80-93].

Conclusion

The result shows that PICS bag was the best storage technique among those compared when certain criteria were considered. Tobit model shows that the ‘use of PICS bag among others had the probability and intensity to reduce PHL. ‘Determinants of choice to store or not to store grains using PICS bag’ shows that awareness creation on PICS, storage of cowpea by farmer, will encourage farmers to store their grains using the PICS bag. The result concluded that the use of Non-PICS storage techniques necessitated the use of insecticide (protectants), while the use of PICS requires little or no protectants, since past literature posited that the use of protectant possess health hazards for consumers of cereal grains, PICS bag should then be disseminated, promoted and made available to farmers at affordable prices.

Appendixces

ANOVA model

Analysis of variance was used to test for differences in post-harvest variables among available storage techniques, specifically to see how PICS bag fared among other storage methods. This is complemented with the use of least square difference.

Analysis of variance (ANOVA)

Source of variation	Sum of Square (SS)	Degree of Freedom (DoF)	Mean Square (MS)	F ratio
Between treatment	Sum of square between (SSB)	k-1	Mean Square Between (MSB)	F ratio
Error	Sum of square error (SSE)	n-k	Mean Square Error (MSE)	
Total	Sum of square total (SST)	n-1		

Least Significant Difference (LSD)

$$LSD_{1,0} = t_{0.05/2,DFW}\sqrt{MSW\left({}^{1}/_{n_1} + {}^{1}/_{n_0}\right)}$$

Where: t=critical value from the t-distribution table MSw = mean square within, obtained from the results of the ANOVA test; n = number of scores used to calculate the means Vvaa.

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