

Article

Farmers' Perception of the Use and Benefits of Cowpea Storage Methods in Northern Ghana

Ryan Kusi Osei-Asibey ^{1,2} , Faustina Dufie Wireko-Manu ^{1,*}, Robert Aidoo ³, Stanley Boakye-Achampong ³ , Felix Charles Mills-Robertson ⁴ and Dieudonne Baributsa ⁵ 

¹ Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology (KNUST), PMB UPO, Kumasi, Ghana; ryan.kusi@ktu.edu.gh

² Department of Food and Postharvest Technology, Koforidua Technical University (KTU), Koforidua 03420, Ghana

³ Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology (KNUST), PMB UPO, Kumasi, Ghana; raidoo.canr@knust.edu.gh (R.A.); sbabigstan@gmail.com (S.B.-A.)

⁴ Department of Biochemistry and Biotechnology, Kwame Nkrumah University of Science and Technology (KNUST), PMB UPO, Kumasi, Ghana; fcmrobertson.cos@knust.edu.gh

⁵ Department of Entomology, Purdue University, West Lafayette, IN 47907, USA; dbaribut@purdue.edu

* Correspondence: fdwireko-manu.cos@knust.edu.gh; Tel.: +233-207-010-712

Abstract: Insect infestation during the storage of cowpea is a major challenge among smallholder farmers in sub-Saharan Africa (SSA). Farmers use various postharvest storage methods to deal with insect pests, including insecticides, which may result in health and environmental hazards. Four hundred (400) cowpea farmers were interviewed on their perceptions and preference of different storage methods in Northern Ghana. About 58% of farmers applied insecticides, 50% used ash, and 42% used hermetic triple-layer bags (Purdue Improved Crop Storage, PICS) to store cowpea. Most farmers (85.6%) preferred the PICS technology for its effectiveness (compared to insecticides, ash, and botanicals). Reasons for the non-use of PICS bags included unavailability (39.5%) and high price (11.7%). Farmers perceived that storing cowpea in PICS bags lowered pesticide-related health risks for both farmers and consumers. Thus, there is a need to improve the availability and affordability of PICS bags in Northern Ghana.

Keywords: grain storage; insect pests; postharvest losses; airtight technologies; food safety



Citation: Osei-Asibey, R.K.; Wireko-Manu, F.D.; Aidoo, R.; Boakye-Achampong, S.; Mills-Robertson, F.C.; Baributsa, D. Farmers' Perception of the Use and Benefits of Cowpea Storage Methods in Northern Ghana. *Sustainability* **2022**, *14*, 5129. <https://doi.org/10.3390/su14095129>

Academic Editor: Giuseppe Mannino

Received: 28 March 2022

Accepted: 20 April 2022

Published: 24 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Globally, over 6.1 million tons of cowpea are produced annually, with about 5.2 million tons produced and consumed in Africa [1–4]. Ghana is among the topmost cowpea producers in Africa and has over 90% of its annual production coming from its three northern regions (Northern, Upper East, and Upper West regions) [1,4–7]. Cowpea farmers in Northern Ghana sell immediately after harvest or store their cowpea to obtain better prices a few months later, mostly during the lean season. However, insect pests are a major challenge during cowpea storage by smallholder farmers. Insect infestation in stored grain is often exacerbated by environmental conditions such as high temperature and relative humidity leading to spoilage and contaminations [8]. Consequently, within the first three (3) months into storage, their unprotected cowpea is rendered unfit for human consumption or cultivation [9,10]. Hence, cowpea farmers need to use safe and effective cowpea preservation methods to maintain the quality of their grains during storage [3].

Across sub-Saharan Africa (SSA), preserving stored cowpea using synthetic insecticides is common among smallholder farmers [11,12]. Insecticides are preferred because they are easy to use and effective [13]. Using synthetic insecticides prevents pest damage but with potentially adverse effects on both consumers and the environment [14]. Often,

chemical application for cowpea preservation by farmers results in misuse and overuse due to a lack of proper training [12,15].

However, even before the introduction of synthetic chemicals in Northern Ghana, farmers were using traditional methods for cowpea preservation, including botanicals and inert dust. Botanicals are obtained from a myriad of plants, applied in different forms, leading to variances in effectiveness [11]. Inert materials such as fine sand, ash, or lime are mixed with cowpea grains, hence creating physical barriers to insect movement and reproduction [10,16]. This notwithstanding, the amount of inert material needed for effective protection makes this method less practical for commercial storage of cowpea [9].

In recent years, Purdue Improved Crop Storage (PICS) bags were introduced to cowpea farming communities in several African countries, including Ghana [17,18]. The technology is now widely used to store dry cereal and legume grains across SSA [18–20]. The PICS technology has received massive acceptance among farmers in SSA, and its use is being expanded to other regions of the world, including Asia and Latin America [21,22]. Smallholder farmers are more attracted to storing cowpea in PICS bags because they are cost-effective and fit into many of their socio-economic conditions [23]. Other brands of hermetic bags (i.e., SuperGrain bags, Zerofly, etc.) have emerged, but PICS retains the largest share of the market [24–26].

Though all these storage methods are available for cowpea storage, there is limited understanding of smallholder farmers' perception of their use and benefits. This study was carried out to investigate the use, perception, and preference of different postharvest storage methods among cowpea farmers in the Northern and Upper West regions of Ghana.

2. Materials and Methods

2.1. Study Area, Sample Size, and Sampling Technique

This study was conducted in two of the three regions within the Guinea Savannah agro-ecological zone- the Northern and Upper West regions. Based on national statistics, these regions are known to be the major cowpea producing areas in the country [7]. By using a multistage sampling technique, data were collected from 400 cowpea farmers across two randomly selected districts in each of the two regions. In consultation with the Regional Agricultural Development Units and stakeholders involved in the cowpea value chain, districts within each region that actively cultivate cowpea were listed. Two districts were randomly chosen from the list in each region: Tolon and Yendi in the Northern region and Nadawli/Kaleo and Daffiama-Bussie-Issah in the Upper West region. Cowpea growing communities within each district were enlisted with the help of agricultural extension agents. In each district, 10 communities were randomly selected through balloting. In each community, cowpea farmers who stored cowpea and had used different postharvest (PH) storage methods were enlisted, and 10 respondents were randomly selected through balloting. Thus, a total of 400 cowpea producers were interviewed.

2.2. Data Collection and Analysis

A pre-test of the questionnaire was performed to assess and revise the data collection tool before the interview of respondents. The research survey was conducted between June and July 2017. Two teams of five trained enumerators (one per region) conducted the interviews. Data were collected through face-to-face interviews using a standardized structured questionnaire with open and closed-ended questions. Information sought included demographics (age, household size, farm size, educational level, and cowpea farming experience), postharvest storage practices, and perception and preferences for the different storage methods.

The socio-economic data were analyzed using standard descriptive and inferential statistical tools. Farmers' preference and perception of the effectiveness of the storage methods were elicited using a four-point Likert scale: 1—most preferred/very effective, 2—preferred/effective, 3—least preferred/somewhat effective, and 4—not preferred/ineffective [27–32]. The perception of benefits that farmers associate with the various

storage methods was elicited using a Likert scale ranging from 1—strongly disagree to 5—strongly agree [33]. Any mean score between 1 and 1.5 means strongly disagree, and between 1.5 and 2.5 means disagree. Furthermore, a mean average between 2.5 and 3.5 means that respondents are neutral about that statement. Any mean score between 3.5 and 4.5 means that farmers agree with this statement. Any mean between 4.5 and 5 means farmers strongly agree with this statement [34]. Respondents were able to make a meaningful distinction between categories on a 5-point Likert scale due to its shortness [35]. Finally, the average scores were then used to analyze the preferences and perceptions of cowpea farmers in relation to the different storage methods. Simple means were used to interpret the ranking data. The means were determined using the following equation:

$$\bar{x} = \frac{\sum x_i}{N} \quad (1)$$

where,

x_i = the response (i.e., code on the Likert scale) selected by the i th respondent
 N = total number of respondents in the study.

3. Results

3.1. Demographic Characteristics and Farm-Level Information of Cowpea Farmers

Demographic and farm-level information of respondents are presented in Table 1. The results show that among the respondents, 66.7% were male, 86.7% were married, 60% did not have formal education, and had an average age of 43.9 years.

Table 1. Summary of demographics and farm-level characteristics of cowpea farmers in Northern and Upper West regions of Ghana.

Parameters	Variables	Northern Region (<i>n</i> = 200)	Upper West Region (<i>n</i> = 200)	Pooled (<i>n</i> = 400)
Gender (%)	Male	71	62.5	66.7
	Female	29	37.5	33.3
Age (years)	20–30	17.5	18.5	18
	31–40	30	20.5	25.3
	41–50	28.5	28.5	28.5
	Above 50	24	32.5	28.2
Marital status (%)	Married	93.5	80	86.7
	Single	3	7.5	5.3
	Widowed	1.5	8.5	5
	Divorced/Separated	2	4	3
Primary Occupation (%)	Farming	94.5	95	94.7
	Salary worker	1.5	2.5	2
	Artisan/Vocation	1.5	0.5	1
	Trading/Commerce	2	2	2
	Other	0.5	0.0	0.3
Level of Education (%)	None	60	60	60
	Non-Formal/Basic	26	22.5	24.2
	Secondary	11	15.5	13.3
	Tertiary	3	2	2.5
Cowpea farm size (ha)	<0.4	5.5	6.5	6
	0.4–1.2	87.5	83	86
	1.3–2.4	6	7.5	6.5
	2.5–3.6	0.5	1.5	1
	>3.7	0.5	0.5	0.5

About 95% of respondents indicated farming as their primary occupation, with an average cowpea farm of 0.8 ha and 14.5 years of cowpea production experience. Most farmers cultivated between 0.4–1.2 hectares during the last cropping season with an average yield of 0.47 t/hectare. A typical household had an average of nine (9) people.

3.2. Cowpea Storage Containers Used by Farmers

Farmers stored their cowpea in different kinds of containers/structures such as woven polypropylene (PP) bags, silos, traditional shed/granaries, and other containers (pots, cement bags, drums, storage baskets/basins, jerry cans, etc.) (Table 2). Most farmers in the Northern region (65.5%) stored their cowpea in woven PP bags, while those in Upper West (43.5%) stored their cowpea in various containers (pots, cement bags, drums, jerry cans, etc.). Overall, the woven PP bag was the predominant storage container used by farmers (41%) in the study area. Mud silos and granaries were used by about a fifth of farmers in the Upper West but almost none in the Northern region. Results showed most farmers (86.5%) stored their cowpea inside the house. It is important to note that sometimes cowpea is kept in pods and stored outside. About a fifth of farmers (21%) in Upper West kept their cowpea in an open space (veranda).

Table 2. Storage methods used by cowpea farmers in the Northern and Upper West regions of Ghana.

Storage Methods	Northern Region (<i>n</i> = 200)	Upper West Region (<i>n</i> = 200)	Pooled (<i>n</i> = 400)
<i>Storage containers (% respondents)</i>			
Woven/PP bags	65.5	16.5	41
Mud silos	0	21	10.5
Traditional shed/granaries	1.5	19	10.3
Other containers (pots, cement bags, baskets, basins, drums, jerrycans)	33	43.5	38.2
<i>Storage location (% respondents)</i>			
Outside (Veranda)	5	21	13
Inside the house (Storeroom, bedroom, Kitchen)	94.5	78.5	86.5
Community/group warehouse	0.5	0.5	0.5

3.3. Grain Protection Methods Used by Farmers

Farmers used various cowpea storage methods, including insecticide application (synthetic and botanicals) on grain kept in woven PP bags, PICS hermetic bags, other hermetic containers (such as jerry cans and plastic bottles), and ash (Table 3). About three-fifths of farmers (58%) used synthetic chemical protectants, 50% used ash and 42% used PICS bags to preserve their stored grains. Though readily available, the use of ash was found to be a tedious and laborious task to perform, especially for preserving large quantities of cowpea (Table 3). Among farmers using PICS bags, 85.6% used the technology because of its high effectiveness (Table 3). About two-fifths of farmers used other types of hermetic containers (e.g., jerry cans, plastic bottles, etc.) because they were readily available (Table 3). Major constraints in the use of any storage methods were unavailability of PICS bags (by about 40% of farmers using the technology) and limited knowledge of the use of botanicals (by 44.2% of farmers using this protection method) (Table 3).

3.4. Farmers' Perceived Preference and Effectiveness of Storage Methods

The stated perceived preference for the various preservation methods varied significantly among the users. Farmers using PICS bags had the highest level of preference (90.5%–most preferred), followed by those using ash (78.1%–preferred) (Table 4).

Similarly, PICS scored highest compared to other preservation methods as 90.5% of respondents using the technology stated it was “very effective”. As for the perceived preference, ash and synthetic insecticide users came in second and third after PICS bags with 73.1% and 51.1% of respondents, respectively, using these storage methods claimed there were “effective”. In order of perceived preference and effectiveness based on collated averages, PICS was ranked the most effective, followed by ash, then synthetic pesticides, then botanicals, and other hermetic containers (Table 4).

Table 3. Reasons and constraints for using storage methods among farmers in the Northern and Upper West regions of Ghana.

Variable	Other Hermetic	PICS	Botanicals	Synthetic Insecticides	Ash
Use of Storage method (%) *	27.8 (n = 111)	41.8 (n = 167)	19 (n = 76)	58.3 (n = 233)	50.3 (n = 201)
<i>Reason for using various storage methods (% respondents)</i>					
Cheaper	32	0.6	33.3	17.4	22.4
Available	40	10.2	26.2	44.9	65.8
Effective	28	85.6	19	33.3	9.7
Chemical-free	-	3.6	-	-	-
Others	-	-	2.4	2.9	-
<i>Constraints in using various storage methods (% respondents)</i>					
Not available	3.3	39.5	0.5	3	0.3
Expensive	0.5	11.7	-	7	-
Limited knowledge	16.2	3	44.2	9	10.2
Not aware	15.5	3.8	15.2	0.5	10.7
Not applicable	27.8	42	19	58.3	50.3

* Percentage may sum to more than 100% for “use of storage method” because respondents may have used more than one storage method.

Table 4. Farmers’ perceived preference and effectiveness of the different cowpea storage methods in the Northern and Upper West regions of Ghana.

Variable	Other Hermetic (n = 111)	PICS (n = 167)	Botanicals (n = 76)	Synthetic Insecticides (n = 233)	Ash (n = 201)
<i>Perceived preference (% respondents)</i>					
Most preferred	6.2	90.5	15.8	16.3	9.5
Preferred	27.9	8.9	39.5	42.9	78.1
Least Preferred	47.7	0.6	40.8	33.5	10.0
Not Preferred	8.1	0.0	3.9	7.3	2.3
Preference score (mean)	2.48	1.10	2.33	2.32	2.06
<i>Perceived effectiveness (% respondents)</i>					
Very effective	9	90.5	11.8	20.4	13.4
Effective	37.8	7.1	40.8	51.1	73.1
Somewhat effective	38.7	1.8	36.8	22.0	10.9
Not effective	14.4	0.6	10.5	6.4	2.5
Perception score (mean)	2.59	1.13	2.46	2.15	2.03

3.5. Farmers’ Perceived Benefits Associated with the Different Storage Protection Methods

Farmers’ assessment of PICS bags on all indicators was high, with a score above four out of five suggesting a positive perception of the technology, while both insecticides and traditional methods varied from 1.00 to 3.69 and 2.87 to 3.95, respectively (Table 5). Farmers perceived that PICS bags reduced the risk of chemical poisoning and maintained grain quality (maintain color, no mold, tasty, etc.), and allowed long-term storage. Respondents perceived that all storage methods (PICS, chemical, and traditional) were able to store grains well (free of insect pests) for a long time (Table 5). However, synthetic insecticides were perceived as a source of food poisoning, with the lowest score of one among all indicators and storage methods. Respondents did not perceive synthetic chemicals to influence the taste of stored cowpea.

Table 5. Perception of the benefits farmers associate with the common postharvest (PH) storage methods used in the Northern and Upper West regions of Ghana.

	Indicator Statements	Mean Scores of Postharvest Storage Methods		
		PICS Technology	Synthetic Insecticides	Traditional Methods (Ash, Botanicals, etc.)
1	This storage method reduces the risk of food poisoning attributed to chemicals	4.39	1.00	3.96
2	Grain stored with this method is of good quality and free of insects	4.33	3.69	3.59
3	Grains stored with this storage method do not get damp or moldy	4.16	3.39	3.41
4	Grains stored with this storage method are more tasty/palatable	4.01	2.83	3.61
5	Grains stored with this storage method reduce discoloration of beans	4.09	3.49	2.87
6	Grains store better and longer with this storage method	4.34	3.54	3.50

4. Discussion

4.1. Demographic Characteristics and Farm-Level Information of Cowpea Farmers

Cowpea is mostly cultivated by male farmers who are married and consider farming as their main occupation. The male dominance in cowpea cultivation on small farms, confirmed by other studies, could be attributed to its high labor input requirements [36–38]. Most of these farmers were experienced in cowpea production, which made them more likely to adopt new and improved postharvest (PH) storage methods [38]. Thus, these farmers may have in-depth knowledge and experience of the use and available PH storage methods in their locality. The respondents produced cowpea on small farms because access to land is becoming a challenge, and also cowpea is considered a minor or alternate crop in Northern Ghana [6]. The high illiteracy rate among the farming populace in Ghana, particularly smallholder farmers, has been previously reported [6,15].

4.2. Cowpea Storage Containers Used by Farmers

Our survey data revealed that cowpea farmers in Ghana stored grains mainly in woven PP bags and kept these bags in rooms within their houses. Farmers kept woven bags containing grains in rooms due to limited access to warehouses. This is probably because smallholders were storing relatively few bags and had neither the capital nor a pressing need to construct warehouses [39]. Although the use of mud silos was common in the Upper West region (UWR), as previously reported [40], it was non-existent in the Northern region (NR). Storage structures including mud silos and traditional shed/granaries were the second most used storage containers in the UWR. Though we found that a fifth of cowpea farmers in the UWR kept their stocks in an open space (veranda), just about 5% of their peers in NR kept their grains outside. Research has documented variations in storage methods used by smallholder farmers in various countries, including Ghana and Uganda [41,42]. These studies showed that differences in storage types among smallholder farmers were due to their locations (districts where they live), access (cost and availability), and other demographic characteristics such as gender.

4.3. Grain Protection Methods Used by Farmers, Level of Preference, and Perceived Effectiveness

The findings of this study show that the majority of cowpea farmers in northern Ghana applied insecticides to their grains before storage. This result agrees with the findings of [37] that most farmers in Ghana store their grains with synthetic chemicals. Many farmers also used ash to protect their stored grains, likely, because of its relative availability at no cost in most households. However, its adoption may be limited because it is tedious and laborious to use for storing large quantities of grains. The use of ash requires a 1:1

proportion volume of ash: cowpea mix for effective preservation; hence ash is typically used for storing seed [9]. About two-fifths of farmers used PICS bags to store cowpea. Similar results were seen in Niger and other countries in West Africa [43,44]. Farmers preferred to use and perceived PICS bags as the most effective PH storage method. This is indicative of the cultural acceptability of bag usage for grain storage and protection, especially since PP bags were also the most predominantly used cowpea storage container. Though PICS bags were preferred by farmers, limited availability was a challenge in rural areas, as seen in other countries in sub-Saharan Africa [24,45].

Other hermetic storage containers such as jerry cans and plastic bottles were used for cowpea preservation in certain households, though they may be used for fetching or storing water. Cowpea farmers perceived these other hermetic containers to be the most ineffective, in spite that these containers were both available and less expensive. This perception of ineffectiveness contradicts what is reported by other studies that hermetic storage methods (e.g., jerrycans) are effective at preserving cowpea [46,47]. Though one-fifths of farmers used botanicals, they had limited knowledge about their usage for storing cowpea. These results are comparable to those obtained by [48], who found that only 20% of farmers used botanicals to store grain. Botanicals were perceived to be cheap, available, and effective. However, many studies have shown botanical pesticides to be less effective compared with synthetic insecticides [49,50].

4.4. Perception of the Benefits Farmers Associate with the Different PH Storage Methods

Cowpea farmers perceived that PICS bags had a positive influence on limiting the growth of mold and reducing the dumpiness of stored cowpea. Moreover, cowpea farmers perceived that the use of PICS bags and traditional methods lowered the incidence of food poisoning while the use of chemical storage increased it. Chemicals (e.g., phostoxin, actellic) methods leave residues in cowpea stocks that could lead to food poisoning for consumers. Aside from residues, food poisoning can also result from mold growth [51] vis-à-vis insect infestation [52]. Both toxigenic and non-toxigenic molds produce mycotoxins which cause food poisoning [51,53]. Various studies have shown that hermetic conditions can maintain drier conditions good enough to reduce dumpiness as well as prevent the formation of molds [46]. From this study, PICS bags are perceived to be more effective at hampering both mold and insect infestation and eliminating food poisoning due to chemical use. This shows that if issues of availability and cost are addressed, most farmers would be willing to use storage technologies such as PICS for cowpea storage.

5. Conclusions

This study was carried out to investigate the use, perception, and preference of different postharvest storage methods among cowpea farmers in northern Ghana. The majority of farmers kept their cowpea grain in woven polypropylene bags and protected the grains from insects using synthetic chemicals, ash, and PICS bags. Aside from effectiveness, farmers were concerned about safety, availability, and affordability when choosing a postharvest storage method. Among the PH storage methods, PICS bags were most preferred, considered safer, and most effective at preserving stored cowpea. However, farmers complained about the unavailability and high cost of PICS bags. Through efforts by the private sector, there is a need to improve the availability and affordability of PICS bags in Northern Ghana.

Author Contributions: Conceptualization, R.K.O.-A.; Investigation, R.K.O.-A. and S.B.-A.; Formal analysis, R.K.O.-A.; Data curation, R.K.O.-A. and S.B.-A.; Writing—Original draft preparation, R.K.O.-A.; Supervision, F.D.W.-M., F.C.M.-R., R.A. and D.B.; Validation, R.A.; Writing—Review and editing, F.D.W.-M., S.B.-A., F.C.M.-R., R.A. and D.B.; Funding acquisition, D.B.; Project administration, F.D.W.-M.; Visualization, D.B.; Resources, D.B. All authors have read and agreed to the published version of the manuscript.

Funding: The authors are thankful to the PICS3 Project (grant# INV-006972) at Purdue University funded by the Bill and Melinda Gates Foundation (BMGF) for supporting this study.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Purdue University (protocol code 1405014885).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Raw data are not publicly available, though the data may be made available on request from the corresponding author.

Acknowledgments: The authors are grateful to all the trained enumerators that helped to carry out the survey and the respondents for taking their time to answer the survey.

Conflicts of Interest: Dieudonne Baributsa is a co-founder of PICS Global Inc., a social enterprise that commercializes postharvest technologies (including PICS bags) to smallholder farmers around the world and hence declares a conflict of interest. The other authors declare no conflict of interest. The funder (Bill and Melinda Gates Foundation) had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Abate, T.; Alene, A.D.; Bergvinson, D.; Shiferaw, B.; Silim, S.; Orr, A.; Asfaw, S. *Tropical Grain Legumes in Africa and South Asia: Knowledge and Opportunities*; International Crops Research Institute for the Semi-Arid Tropics (ICRISAT): Nairobi, Kenya, 2012; pp. 38–42.
2. Ddungu, S.P.; Ekere, W.; Bisikwa, J.; Kawooya, R.; Kalule, D.O.; Biruma, M. Marketing and market integration of cowpea. *J. Dev. Agric. Econ.* **2015**, *7*, 1–11.
3. Langyintuo, A.S.; Lowenberg-DeBoer, J.; Faye, M.; Lambert, D.; Ibro, G.; Moussa, B.; Kergna, A.; Kushwaha, S.; Musa, S.; Ntougam, G. Cowpea supply and demand in West and Central Africa. *Field Crop. Res.* **2003**, *82*, 215–231. [CrossRef]
4. Timko, M.P.; Singh, B.B. Cowpea, a multifunctional legume. In *Genomics of Tropical Crop Plant*; Moore, P.H., Ming, R., Eds.; Springer: New York, NY, USA, 2008; pp. 227–257.
5. Egbadzor, K.F.; Yeboah, M.; Offei, S.K.; Ofori, K.; Danquah, E.Y. Farmers' key production constraints and traits desired in cowpea in Ghana. *J. Agric. Ext. Rural Dev.* **2013**, *5*, 14–20. Available online: <http://www.academicjournals.org> (accessed on 19 April 2018).
6. Akpalu, M.M.; Salaam, M.; Oppong-Sekyer, D.; Akpalu, S.E. Farmers' Knowledge and Cultivation of Cowpea (*Vigna unguiculata* (L.) Verdc.) in Three Communities of Bolgatanga Municipality, Upper East Region, Ghana. *British. J. Appl. Sci. Tech.* **2014**, *4*, 775–792. [CrossRef]
7. Ministry of Food and Agriculture (MoFA). Statistics, Research and Information Directorate (SRID) (MOFA, SRID). 2015. Available online: <https://mofa.gov.gh/site/images/pdf/AGRICULTURE-IN-GHANA-Facts-and-Figures-2015.pdf> (accessed on 12 February 2022).
8. Hubert, J.; Stejskal, V.; Athanassiou, C.G.; Throne, J.E. Health Hazards Associated with Arthropod Infestation of Stored Products. *Annu. Rev. Entomol.* **2018**, *63*, 553–573. [CrossRef]
9. Murdock, L.L.; Seck, D.; Ntougam, G.; Kitch, L.; Shade, R.E. Preservation of Cowpea Grain in Sub-Saharan Africa—Bean/Cowpea CRSP Contributions. *Field Crops Res.* **2003**, *82*, 169–178. [CrossRef]
10. Dari, L.; Tindan, I.P. Control of Cowpea Weevil (*Callosobruchus maculatus*) using Indigenous Storage Methods. *Ghana J. Hort.* **2016**, *12*, 39–49.
11. Obeng-Ofori, D. The use of botanicals by resource poor farmers in Africa and Asia for the protection of stored agricultural products. *Stewart PH Rev.* **2007**, *6*, 1–8. [CrossRef]
12. Zhu, J. Advances in Pesticide Use in the Cocoa Belts and Perceptions of Vegetable Farmers. *J. Hort.* **2015**, *2*, 149. [CrossRef]
13. Stejskal, V.; Vendl, T.; Aulicky, R.; Athanassiou, C. Synthetic and Natural Insecticides: Gas, Liquid, Gel and Solid Formulations for Stored-Product and Food-Industry Pest Control. *Insects* **2021**, *12*, 590. [CrossRef]
14. Obeng-Ofori, D. Residual insecticides, inert dusts and botanicals for the protection of durable stored products against pest infestation in developing countries. In Proceedings of the 10th International Working Conference on Stored Product Protection, Estoril, Portugal, 27 June–2 July 2010; Volume 425, pp. 774–788.
15. Ntow, W.J.; Gijzen, H.J.; Kelderman, P.; Drechsel, P. Farmer perceptions and pesticide use practices in vegetable production in Ghana. *Pest Manag. Sci.* **2006**, *62*, 356–365. [CrossRef] [PubMed]
16. Abd El-Aziz, S.E. Control Strategies of Stored Products Pests. *J. Entomol.* **2011**, *8*, 101–122. [CrossRef]
17. Baributsa, D.; Lowenberg-DeBoer, J.; Murdock, L.L.; Musa, B. Profitable chemical-free storage technology for small-holder farmers in Africa: Opportunities and Challenges. In Proceedings of the 10th International Working Congress on Stored Product Protection, Estoril, Portugal, 27 June–2 July 2010.
18. Murdock, L.L.; Baributsa, D. Hermetic storage for those who need it most—Subsistence farmers. In Proceedings of the Eleventh International Working Conference on Stored Product Protection, Chang Mai, Thailand, 24–28 November 2014; pp. 310–323.

19. Baributsa, D.; Abdoulaye, T.; Lowenberg-DeBoer, J.; Dabire, C.; Moussa, B.; Coulibaly, O.; Baoua, I. Market building for post-harvest technology through large-scale extension efforts. *J. Stored Prod. Res.* **2014**, *58*, 59–66. [CrossRef]
20. Sanon, A.; Dabiré, L.C.; Ba, N.M. Triple-bagging of cowpeas within high density polyethylene bags to control the cowpea beetle *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). *J. Stored Prod. Res.* **2011**, *47*, 210–215. [CrossRef]
21. Baributsa, D.; Ignacio, M.C.C.D. Developments in the use of hermetic bags for grain storage. In *Advances in Postharvest Management of Cereals and Grains*; Maier, D.E., Ed.; Burleigh Dodds Science Publishing: Cambridge, UK, 2020; p. 28. [CrossRef]
22. Odjo, S.; Burgueno, J.; Rivers, A.; Verhulst, N. Hermetic storage technologies reduce maize pest damage in smallholder farming systems in Mexico. *J. Stored Prod. Res.* **2020**, *88*, 101664. [CrossRef]
23. Jones, M.; Alexander, C.; Lowenberg-DeBoer, J. *An Initial Investigation of the Potential for Hermetic Purdue Improved Crop Storage (Pics) Bags to Improve Incomes for Maize Producers in Sub-Saharan Africa*; Working Paper; Department of Agricultural Economics, Purdue University: West Lafayette, IN, USA, 2011; Volume 11, p. 3.
24. Baributsa, D.; Njoroge, A.W. The use and profitability of hermetic technologies for grain storage among smallholder farmers in eastern Kenya. *J. Stored Prod. Res.* **2020**, *87*, 101618. [CrossRef]
25. Baoua, I.B.; Amadou, L.; Lowenberg-DeBoer, J.D.; Murdock, L.L. Side by side comparison of GrainPro and PICS bags for postharvest preservation of cowpea grain in Niger. *J. Stored Prod. Res.* **2013**, *54*, 13–16. [CrossRef]
26. Villers, P.; Navarro, S.; De Bruin, T. New applications of hermetic storage for grain storage and transport. In *Fumigation, Modified Atmospheres and Hermetic Storage, Proceedings of the 10th International Working Conference on Stored Product Protection, Estoril, Portugal, 27 June–2 July 2010*; Navarro, S., Riudavets, J., Eds.; Julius-Kuhn-archiv: Quedlinburg, Germany, 2010; Volume 425, pp. 446–452.
27. Brown, S. ANR Program Evaluation Iowa State University Extension. 2010, pp. 1–4. Available online: <https://jordan.kmportal.com/resources/likert-scale-examples-for-surveys> (accessed on 12 February 2022).
28. Papanna, K.M.; Kulkarni, V.; Tanvi, D.; Lakshmi, V.; Kriti, L.; Unnikrishnan, B.; Akash, S.; Tejesh, S.; Sumit, K.S. Perceptions and preferences of medical students regarding teaching methods in a Medical College, Mangalore India. *Afr. Health Sci.* **2013**, *13*, 808–813. [CrossRef]
29. Maoba, S. Farmers' Perception of Agricultural Extension Service Delivery in Germiston Region, Gauteng Province, South Africa. *S. Afr. J. Agric. Ext.* **2016**, *44*, 167–173. [CrossRef]
30. Azumah, S.B.; Donkoh, S.A.; Joseph, A.A. The perceived effectiveness of agricultural technology transfer methods: Evidence from rice farmers in Northern Ghana. *Cogent Food Agric.* **2018**, *4*, 1503798. [CrossRef]
31. Taderhoost, H. What Is the Best Response Scale for Survey and Questionnaire Design; Review of Different Lengths of Rating Scale/Attitude Scale/Likert Scale. *Hamed Taherdoost* **2019**, *8*, 1–10.
32. Höchsmann, C.; Fearnbach, N.; Dorling, J.L.; Fazzino, T.L.; Myers, C.A.; Apolzan, J.W.; Martin, C.K. Preference, Expected Burden, and Willingness to Use Digital and Traditional Methods to Assess Food and Alcohol Intake. *Nutrients* **2021**, *13*, 3340. [CrossRef] [PubMed]
33. Likert, R. A technique for the measurement of attitudes. *Arch. Psychol.* **1932**, *140*, 1–55.
34. Amponsah, S.K.; Addo, A.; Dzisi, K.; Asante, B.; Daniel, A. Assessment of rice farmers' knowledge and perception of harvest and postharvest losses in Ghana. *Cogent Food Agric.* **2018**, *4*, 1471782. [CrossRef]
35. Hansson, H.; Ferguson, R.; Olofsson, C. Psychological constructs underlying farmers decisions to diversify or specialise their businesses—An application of theory of planned behaviour. *J. Agric. Econ.* **2012**, *63*, 465–482. [CrossRef]
36. Mohammed, A.-R. Evaluation of Storage Facilities for Groundnut and Cowpea in the Zabzugu and Saboba Districts in the Northern Region of Ghana. MPhil Thesis, Department of Horticulture, KNUST, Kumasi, Ghana, 2014.
37. Abdulai, M.; Etwire, P.M.; Wiredu, A.N.; Baributsa, D.; Lowenberg-DeBoer, J. Cowpea storage practices and factors that influence choice in Ghana. *Afr. J. Crop Sci.* **2017**, *5*, 177–185.
38. Bashir, M.B.; Ndaghu, A.A.; Nakwe, S.H.G.; Abdulazeez, A.W.; Samuel, R.T. Adoption of Cowpea Production Technologies among Farmers in Taraba State, Nigeria. *J. Agric. Vet. Sci.* **2018**, *11*, 37–46.
39. Abdullahi, A.; Usman, I.S.; Girei, A.A.; Gambo, I. Examination of indigenous storage methods of Cowpea (*Vigna unguiculata*) in Mubi South Local Government Area, Adamawa State, Nigeria. *Econ. Eng. Agric. Rural Dev.* **2016**, *16*, 9–16.
40. Dramani, K. Comparative Study of Cowpea Storage in Different Storage Structures. Master's Thesis, Department of Agricultural Engineering, KNUST, Kumasi, Ghana, 2010.
41. Addo, S.; Birkinshaw, L.; Hodges, R.J. Ten years after the arrival in Ghana of the large grain borer: Farmers responses and adaptation of IPM strategies. *Int. J. Pest Manag.* **2002**, *48*, 315–325. [CrossRef]
42. Anthony, T.; Makombe, G.; Kele, T. An Analysis of the Characteristics of Maize Storage Types Used by Smallholder Producers in Developing Countries: A Case of Uganda. *Am. J. Ind. Bus. Manag.* **2019**, *9*, 1524–1555. [CrossRef]
43. Moussa, B.; Abdoulaye, T.; Coulibaly, O.; Baributsa, D. Adoption of on-farm hermetic storage for cowpea in West and Central Africa in 2012. *J. Stored Prod. Res.* **2014**, *58*, 77–86. [CrossRef]
44. Ibro, G.; Sorgho, M.C.; Idris, A.A.; Moussa, B.; Baributsa, D.; Lowenberg-DeBoer, J. Adoption of cowpea hermetic storage by women in Nigeria, Niger and Burkina Faso. *J. Stored Prod. Res.* **2014**, *58*, 87–96. [CrossRef]
45. Rabé, M.M.; Baoua, I.B.; Baributsa, D. Adoption and Profitability of the Purdue Improved Crop Storage Technology for Grain Storage in the South-Central Regions of Niger. *Agronomy* **2021**, *11*, 2470. [CrossRef]
46. Aboagye, D.; Darko, J.O.; Banadda, N. Comparative study of hermetic and non-hermetic storage on quality of cowpea in Ghana. *Chem. Biol. Technol. Agric.* **2017**, *4*, 10. [CrossRef]

47. Baoua, I.B.; Amadou, L.; Margna, V.; Murdock, L. Comparative evaluation of six storage methods for postharvest preservation of cowpea grain. *J. Stored Prod. Res.* **2012**, *49*, 171–175. [[CrossRef](#)]
48. Utono, I.M.; Claire Coote, G.G. A survey of systems of grain storage and management of insect pests in stored grain in Kebbi state. *IOSR-JAVS* **2013**, *3*, 51–61. [[CrossRef](#)]
49. Cherry, A.J.; Abalo, P.; Hell, K.; Korie, S. Farm-scale trials to compare the entomopathogenic fungus *Beauveria bassiana* with pirimiphos methyl + deltamethrin and essential oil of lemon grass for protection of stored cowpea against *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Ann. Appl. Biol.* **2007**, *7*, 1–4. [[CrossRef](#)]
50. Brisibe, E.A.; Adugbo, S.E.; Ekanem, U.; Brisibe, F.; Figueira, G.M. Controlling Bruchid Pests of Stored Cowpea Seeds with Dried Leaves of *Artemisia annua* and two other Common Botanicals. *Afr. J. Biotech.* **2011**, *10*, 9586–9592.
51. Khare, K.B.; Loeto, D.; Wale, K.; Salani, M. Seedborne fungi of cowpea [*Vigna unguiculata* (L.) Walp] and their possible control in vitro using locally available fungicides in Botswana. *Int. J. Bioassays* **2016**, *5*, 5021–5024.
52. Venâncio, A.; Paterson, R. The Challenge of Mycotoxins. In *Food Safety: A Practical and Case Study Approach*; Springer: Boston, MA, USA, 2004; pp. 26–49.
53. Popoola, A.R.; Adeoti, A.Y.A.; Idakwo, P.Y. Incidence of Moulds in some varieties of stored cowpea and peanuts in Maiduguri, Nigeria. *ASSET Ser. A* **2003**, *3*, 163–169.