



FACTORS INFLUENCING THE ADOPTION OF SOLAR-POWERED COLD STORAGE TECHNOLOGY IN AMONG VEGETABLE MARKETERS IN NORTHEAST, NIGERIA

¹Manu, I., ²Abdullahi, S., ³Danwanka, H. A., ³Sani, R. M.

¹Department of Agricultural Education, Federal College of Education (Technical) Gombe

²Department of Agricultural Extension and Rural Development,
Abubakar Tafawa Balewa University, Bauchi

³Department of Agricultural Economics, Abubakar Tafawa Balewa University, Bauchi

Corresponding Author's Email: manuibrahim683@gmail.com, **GSM:** 08023785334

ABSTRACT

The study examined the factors influencing adoption of solar powered cold storage technology in Northeast, Nigeria. A multi-stage sampling technique was used to select 455 vegetable marketers from the study area. Primary data were collected using structured questionnaires and analyzed using descriptive and inferential statistics. The results showed that the respondents had a mean age, household size, marketing experience and income of 43 years, 10 persons, 23 years and ₦174,516.85, respectively. Furthermore, most (97% and 95%) of the respondents were males and married while majority (85%) had secondary education. Most (93% and 99.2%) of the respondents belong to cooperative society and had no access to extension services. The results also revealed that the technology offers significant improvements over existing technologies and it is compatible with the existing values and needs of vegetable marketers with a mean of 2.9, respectively. The technology is easy to understand and can be experimented on a limited scale, with a mean of 2.6 and 2.4, respectively. The result further revealed that the advantage of the technology can be easily observed and measured (2.5), accessible (2.3), affordable (1.7) and practiced with low risk (2.3). The logit regression result revealed that marital status and membership of cooperatives were positive and significant ($P < 0.05$) while, monthly income was positive and significant ($P < 0.01$) in influencing the adoption of solar powered cold storage. The study concluded that marital status, membership of cooperative societies and monthly income were the significant factors influencing the adoption of solar powered cold storage technology in the study area. The study therefore, recommends that, Government, NGOs and financial institutions should collaborate to provide financial assistance such as low-interest loans, grants, or subsidies to the marketers, vegetable marketers should partner with solar technology companies to develop affordable cold storage solutions that suit their financial capacities and government and private sector stakeholders should prioritize funding and constructing additional cold storage facilities for vegetable marketers.

Keywords: Adoption, Solar, Storage, Vegetables, Marketers

INTRODUCTION

Agriculture plays a vital role in Nigeria's society and economy. For example, in 2020, agriculture accounted for over 24% of the total gross domestic product (GDP) and two-thirds of the work force (FAO, 2020). Nigeria is also the world's fifth largest producer of vegetables and eighth largest producer of fruits, making it an agricultural giant of Africa (FAO, 2022). The production of these fresh produce is largely carried out by smallholder or marginal farmers who often grow them on farms under 4 hectares. Ricciardi, *et al.* (2018). These farmers, who primarily rely on traditional farming practices, account for almost 90% of the total food production. Gekonge (2021). Nigeria's agriculture sector loses an estimated NGN 110 trillion to post-harvest losses (PHL) due to lack of sufficient storage, agro-processing, and transportation infrastructure accessible to farmers, fishermen and retailers USAID (2022). There is a growing demand for both stationary and mobile cold storage systems, from farms to markets, as a result of the combination of high temperatures that increase the rate of decaying, long distances traveled, and the prolong timespan in transit due to bad road conditions Bolarin and Bosa (2015). These losses are specifically, severe in the long-haul transport of fruits and vegetables, of which half of the total post-harvest losses (PHL) of up to 60% occur during transportation (FAO, 2022). According to official estimates by the Food and Agriculture Organization



of the United Nations (FAO), global post-harvest losses (PHL) can reach up to 20% for cereals, 30% for dairy and fish, and 40% for fruit and vegetables FAO (2020). This level of waste is devastating, particularly in Africa where approximately 250 million people (20% of the continent's population) are undernourished. In Sub-Saharan Africa, for example, an estimated US\$4 billion worth of food, which could feed over 48 million people, is lost every year due to post-harvest losses FAO (2020).

In more recent times, solar-powered cold storage technologies have been recognized as a sustainable and inexpensive solution to help under-resourced farmers /marketers avoid post-harvest losses on fruits and vegetables (Kitinoja, 2013). Evidence shows that if given necessary policy and support, solar-powered cold storage technologies offer several socio-economic and environmental benefits to farmers and food suppliers, particularly those in off-grid locations. In Nigeria, the introduction of affordable solar-powered cold storage facilities for vegetable farmers and traders mitigated losses of more than 5000 tonnes of fresh vegetables and fruits that could occur during storage and transportation, significantly increasing farmers' and traders' monthly profits (Ikegwuonu & Odeyemi 2021). Solar powered cold storage have been increasingly recognized as a promising tool to address a multiple of challenges emerging in increasingly complex food systems in developing countries, including food loss and waste, food safety, food and nutrition security, poverty and economic growth and environmental sustainability (Takeshima *et al.*, 2021). Cold storages have become increasingly important technologies to reduce food loss and food waste globally, including developing countries, by reducing microbial growth that causes spoilage (Hassler and Baysal-Gurel 2019; IFPRI, 2020; Mayton, *et al.*, 2020 and Kashyap & Agarwal, 2020). Cold-storage is also expected to reduce the growth of most human pathogens, ensuring enhanced food safety (Ucar and Ozcelik, 2013).

Solar-powered cold storage technologies have been highly recommended as a cost-effective and sustainable solution to avoid food losses on perishable products, especially in low-income economies where the vast majority of rural residents have no access to efficient cooling technologies (Ismail, *et al.*, 2021). In more recent years, a few non-governmental organizations in East and West Africa have ventured to promote and deploy solar-powered cold storage technologies as a solution to minimize food losses experienced by farmers found in non-electrified Cold storage enhances the efficiency of cooling inside the room to a large amount. The post-harvest cooling is needed to speedily eliminate field heat, reduce the growth of pathogens and the generation of ethylene (Sunmonu, *et al.*, 2014). Adoption of agricultural technology is a critical factor in enhancing food security, increasing agricultural production, and promoting sustainable farming practices. Rasyid, & Ningsih, (2024). Agricultural technologies include a varied range of innovations, from traditional practices to modern biotech and precision agriculture methods. These technologies not only improve crop yields and resource productivity but also help in the mitigation of environmental deprivation. Sulochna, *et al.* (2023).

The adoption of solar cold storage technology represents a transformative method in mitigating post-harvest losses of fruits and vegetables, especially in developing regions where traditional cold storage facilities are often scarce or absent. A significant portion of agricultural produce, particularly perishables, is lost after harvest due to inadequate storage facilities. Kaur, & Watson, (2024). The high levels of postharvest food loss in Nigeria have raised concerns about food security and rising poverty, particularly for agriculture-dependent households. Ogwu *et al.* (2024). Post-harvest losses of food have resulted in drying up the incomes of poor and economically vulnerable farmers/traders whose earnings are inconsistent (Ridolfi, *et al.*, 2018). According to Mujuka, *et al.* (2020) more than 70 percent of agriculture-dependent households (farmers, transporters, vendors, processors, etc.) lose an average of 15% of their income due to postharvest food losses" This situation will elevate poverty, household food shortages and malnutrition as many poor marketers would not feed themselves and their families. (Sonka, *et al.*, 2023). Due to lack of cost-effective solution to minimize postharvest losses, farmers /marketers are forced to sell their produce at a lower price immediately after harvesting, earning low returns, thereby getting stuck in the cycle of poverty (Tefera, *et al.*, 2016). It is against this backdrop this study wish to be conducted. The broad objective



of study was to analyzed factors influencing the adoption of solar powered cold storage technology among vegetable marketers while the specific objectives were to;

- i. describe the socio-economic characteristics of the respondents in the study areas;
- ii. examine the level of adoption of solar powered cold storage technology; and
- iii. Determine factors influencing the adoption of solar powered cold storage technology among the respondents.

METHODOLOGY

The Study Area

The study was carried out in Northeast, Nigeria. Northeast consists of six (6) states of Adamawa, Bauchi, Borno, Gombe, Taraba and Yobe. However, the study was conducted in four (4) states of Adamawa, Bauchi, Gombe and Yobe states, respectively. The study area is located between Latitude 90 08' to 140N and Longitude 80 68' to 150E. The area occupies a land mass of 280,419 km² (National Bureau of Statistics (NBS, 2017). According to National Population Census NPC, (2006) the region has a population of 29, 470, 062 people based on 2006 annual population growth rate of 3%. The main economic activities in the area include; farming (crop and livestock), fruits and vegetables production, hunting, fishing, food processing, transportation and craft with inputs largely sourced from government. The average population density is 89 persons per Km², while the mean annual rainfall ranges from less than 250 mm in the Northern Sahel to 1500 mm in the derived savannah. Northeast Nigeria is a suitable area to conduct this study because the demand for fresh horticulture commodities has been rising as a result of population growth and urbanization, and the region is one of the largest producers of major vegetable commodities within Nigeria (Nkonya, *et al.*, 2020). At the same time, the region's population continues to suffer from micronutrient deficiencies and lack of stable access to electricity.

Sampling Procedure and Sample Size

A multi-stage sampling technique was employed in selecting respondents for the study. The first stage, involved purposive selection of four (4) states based on their participation in horticulture production and marketing namely; Adamawa, Bauchi, Gombe and Yobe states. The second stage, involved purposive selection of six (6) horticulture markets in the four states namely; Jimeta ultra-modern market, Yola by-pass market, Muda lawan market, Wunti market, Gombe main market, Potiskum main market due to the presence of solar powered cold storage technology (installed in the markets). The third stage, involved selection of 30% of the respondents in the selected markets making a total of 455 respondents as a sample size for the study drawn from the population.

The sample size for this study was arrived at using Taro's Yamane formula. The formula is given as:

$$n = \frac{N}{1 + (N \cdot e)^2} \quad \dots (1)$$

where; n = sample size.

N = population size.

E = margin error (5%)

Table 1: Sample Size Selection

State	Horticulture market	Population	Sample Size (30%) Proportion
Adamawa	Jimeta ultra-modern market	246	74
	Yola by-pass market	285	86
Bauchi	Muda Lawan market	258	77
	Wunti market	192	58
Gombe	Gombe main market	221	66
Yobe	Potiskum Main market	316	94
TOTAL		1,518	455

Source: Field Survey, 2023.



Method of Data Collection and Analysis

Data for the study were collected through the administration of structured questionnaires to the respondents by the help of trained enumerators under the supervision of the researcher. Both descriptive and inferential statistics were used in analyzing the data. Descriptive statistics used include; frequency distribution, percentages, means and ranking. While, inferential statistics logit regression model.

Logit Model Specification

This model was used to achieve objective i determine the factors that influence adoption of solar-powered cold storage technology among vegetable marketers in the study areas. The Logit model was based on cumulative logistic probability. Logit model assumes that the underlying stimulus is a probability of technology adoption. The behavioral model is $Y_i = g [1i]$, where y_i is the observed response for the i th observation. That is binary variable $y_i = 1$ for adoption and $y_i = 0$ for non-adoption. The probability of technology adoption model is implicitly specified as;

$Y = F(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8)$ and explicitly as follows

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + e.$$

Where:

Y = Adoption (Which is a dummy variable (Adopters = 1 and 0 otherwise)

X_1 = Age (years)

X_2 = Sex (male = 1, female = 0)

X_3 = Marital status (married = 1, otherwise = 0)

X_4 = Household size (number of persons)

X_5 = Educational level (number of years spent in formal education)

X_6 = Marketing experience (Number of years in vegetable marketing)

X_7 = Membership status (member=1, non-member=0)

X_8 = Income of the vegetable marketer (Naira/month)

$X_1 - X_8$ = estimated parameters

b_0 = Constant

$b_1 - b_8$ = Coefficient of estimated parameters

e = Error term

RESULT AND DISCUSSION

Socio-economic Characteristics of the Respondents

The result from Table 2 shows that the age of the vegetable marketers in the study areas ranged between 22 – 67 years. The mean age was 43 years which is considered active and productive age. Out of which majority 58.9% were within the age bracket of 34-55 years. While, 22%, 17.3%, and 0.92% of the respondents were within age of 22-33, 55-66, and above 67 years respectively. This assertion agrees with the findings of Takeshima, *et al.* (2023). in their study on “Solar-powered cold storage and agri-food market modernization in Northeast, Nigeria”. where they reported that the mean age of vegetable marketers was 42 years. Similarly, Korie, *et al.* (2023). in their study on “Assessment of factors influencing adoption of tomato post-harvest loss-reduction technologies in Kaduna state, Nigeria” reported that the mean age of the respondents in the study area was 42.5. The result further revealed the minimum household size of the marketers was 1 person and the maximum was 26 persons. The mean household size was 10 persons. Out of which 39% of the marketers had household size of 8-13 persons. while, 33.9%, 23.8%, 2.2% and 0.9% had 2-7, 14 -19, 20 -25, and 67 and above persons respectively. Sebatta, *et al.* (2015), reported bigger household sizes supply the required labour for value addition activities, thus reducing the need for hired labour to undertake postharvest practices. This result agrees with the findings of Takeshima, *et al.* (2023). in their study on Solar-powered cold storage and agri-food market modernization in Nigeria reported that the mean household size of vegetable marketers in the study areas was 10 persons.



Table 2: Distribution of Respondents Based on Socio-economic Characteristics (n=445)

Variable	Frequency	Percentage	Mean
Age(years)			
22-33	102	22.9	43
34-44	132	29.7	
45-55	130	29.2	
Sex			
Male	431	96.9	
Female	14	3.1	
Marital Status			
Married	437	98.2	
Divorced	8	1.8	
Education Level			
No formal	25	5.6	
Primary	42	9.4	
Secondary	378	84.9	
Household size			
2-7	151	33.9	10
8-13	174	39.1	
14-19	106	23.8	
20-25	10	2.2	
Marketing Experience (Yrs)			
5-13	105	23.6	23
14-22	137	30.8	
23-31	111	24.9	
32-40	66	14.8	
41 and above	26	5.8	
Membership of Cooperatives			
Yes	416	93.5	
No	29	6.5	
Access to Extension			
Yes	24	5.4	
No	421	94.6	
Monthly Income (₦)			
40,000-122,000	116	26.1	₦174,516.85
123,000-205,000	212	47.6	
206,000-288,000	61	13.7	
289,000-371,000	29	6.5	
372,000 and above	27	6.1	

Source: Field Survey; 2023

The result further revealed that 30.8% of the marketers had marketing experience of 14-22 years while, 24.9%, 23.6%, 14.8%, and 5.6% of the marketers had experience of 23-31, 5 – 13, 32 – 40, and 40 and above years of experience, respectively with an average of 23 years. Mutayoba and Ngaruko, (2015). States that farmers experience increased quality and quantity of vegetables produced. Additionally, experience gives farmers bargaining power as well as improved their marketing



networks. Again, a similar study conducted by Al Shadiadeh, *et al.* (2012) showed that farming experience strongly influenced farmers' decision to adopt postharvest practices in vegetable production. The result also revealed that less than half (47.6%) had an annual income of N123,000.00 – N205,000.00 while 26.1%, 13.7%, 6.5% and 6.1% had an annual income of N40,000.00 – N122,000.00, N206,000.00 – N288,000.00, N289,000.00 – N371,000.00, N372,000 and above respectively, with an average monthly income N174,516.85. This agrees with the findings of Olayide *et al.* (2024) in their study on Assessing post-harvest loss of tomato and its implications for food systems transformation in Nigeria Reported a mean monthly income of N141,382.99. The results further shows that most (97%) of vegetables marketers were males. This indicates that vegetable marketing in the study areas was dominated by males and this is because the cultural traditions of the study areas do not allow females to be actively involved in vegetable marketing. This finding affirmed that of Rutta (2022) who reported that majority of the respondents were males. Similarly, Also, Bello, *et al.* (2018) also reported that majority (90%) of the respondents were males

The result also revealed that 98% of vegetables marketers were married. This agrees with the findings of Korie, *et al.* (2023) who reported that majority of the respondents were married. Similar findings were also reported by Sennuga, *et al.* (2020). The result further showed that majority (85%) had secondary education, while 9% and 6% had primary education and no formal education respectively. This finding is in tandem with that of Ajagbe, *et al.* (2014) who reported that majority of the respondents had secondary education followed by Tertiary education and primary education. Similarly, Sani *et al.* (2023) also reported that majority of the respondents had secondary education. The result also revealed that most (93% and 95%) of the vegetable marketers were members of cooperative society and had no access to extension services. This agrees with the findings of Adepoju, *et al.* (2023) who reported that majority of the respondents belong to membership of cooperatives. The findings also agrees with that of Rutta, (2022) who asserted that majority of the respondents had no access to extension services.

Adoption Level of Solar-Powered Cold Storage Technology

The result in Table 4 shows that the attributes of the cold storage technology that influence the level of its adoption. The results revealed that the technology offers significant improvements over existing technologies with a mean of 2.9 which is above the set threshold. The adoption of solar cold storage technology by vegetable marketers is greatly influenced by its relative advantages. Innovations that offer clear benefits are adopted more rapidly (Rogers, 2003). This agrees with the findings of Takeshima *et al.* (2021) who reported that improved product quality can lead to higher market prices and greater consumer satisfaction, motivating marketers to adopt this technology to stay competitive. The results also showed that the technology is compatible with the existing values and needs of vegetable marketers with a mean of 2.9 which is above the set threshold. Innovations that align well with the existing values and norms of users are more likely to be adopted. The higher the compatibility of an innovation, the more rapid its rate of adoption” Rogers, (2003). It is also in line with the *apriori* expectation. This agrees with the findings of Nguyen *et al.* (2024) who reported that respondents are more willing to adopt new technologies, such as precision agriculture tools, when these innovations are perceived as fitting well within their traditional farming practices and local environmental conditions. The result further shows that the technology is easy to understand and use with a mean of 2.6. The complexity of agricultural technology plays a crucial role in shaping farmers' decisions to adopt new innovations. Higher complexity often acts as a barrier, slowing down or discouraging adoption, while simpler technologies tend to be embraced more readily Rogers, (2003).

In addition, the result showed that the technology can be experimented on a limited scale before full implementation with a mean of 2.4. Trialability is a critical factor in determining how quickly and widely a new technology or innovation will be adopted by potential users (Rogers, 2003). The result further showed that the technology can be adopted in incremental steps rather than all at once with a mean of 2.4. Innovations that can be tried on a limited basis tend to have higher adoption rates. Users can assess the benefits of the technology on a smaller scale before deciding to expand its use, leading to increased confidence in its efficacy and utility. Rogers (2003). The results also revealed that the technology can be easily observed and measured by others with a mean of 2.5.



Innovations that yield visible results tend to be adopted more rapidly because potential users can easily see the benefits and effectiveness. Rogers (2003). A study by Moore and Benbasat (1991) highlights that when the benefits of a technology can be easily seen and demonstrated, adoption rates increase. Their findings suggest that observable outcomes make it easier for individuals to form positive attitudes towards the innovation, leading to higher adoption rates. The results further showed that the technology is readily accessible by the vegetable marketers with a mean of 2.3. This implies that agricultural innovations are accessible meaning they are readily available and user-friendly farmers are more likely to adopt them, leading to increased productivity and sustainability. The result also revealed that the technology is not affordable by the vegetable marketers with a mean of 1.7 which is below the set threshold. Affordability is a primary determinant of adoption of a technology. If the cost of new technologies exceeds farmers' financial capacity, adoption rates decline (Rogers, 2003). For example, low-cost, locally adapted technologies have higher acceptance in smallholder farming systems, particularly in developing countries (Karlan et al., 2014). The result also showed that the technology has low risk level with a mean of 2.3. The perceived risk associated with agricultural technology significantly influences its adoption among farmers. Risk aversion, uncertainty about outcomes, and potential financial losses can deter farmers from adopting new innovations, especially in contexts characterized by volatile market conditions, environmental variability, and limited access to information (Feder et al., 1985; Rogers, 2003). According to Feder, Just, and Zilberman (1985), the level of perceived risk directly affects the rate of adoption; technologies perceived as too risky are less likely to be adopted.

Table 3: Adoption Level of Solar-Powered Cold Storage Technology

Technological Attributes (SPCST)	Mean	Decision
The technology offers significant improvements over existing technologies.	2.9	Adoption
The technology is compatible with existing values and needs of the vegetable marketers.	2.9	Adoption
The technology is easy to understand and use by the marketers	2.6	Adoption
The technology can be experimented on a limited scale before full implementation.	2.4	Adoption
The technology can be adopted in incremental steps rather than all at once	2.4	Adoption
The results of the innovation can be easily observed and measured by the vegetable marketers.	2.5	Adoption
The technology is readily accessible by the vegetable marketers	2.3	Adoption
The technology is affordable by the vegetable marketers	1.7	No adoption
The technology has low risk level associated with it.	2.3	Adoption

Source: Field survey, 2023

Mean ≥ 2.0 = Adoption; Mean < 2.0 = No adoption

Factors Influencing the Adoption of Solar Cold Storage Technology in the Study Areas

The result from Table 3 revealed that Marital status was found to be positive and significant ($P < 0.01$) in influencing the adoption of solar-powered cold storage technology in the study area, implying that a unit increase in marriage increases the likelihood of adoption of solar-powered cold storage technology among vegetable marketers by a factor of 2.2088. This disagrees with the findings of Conteh, *et al.* (2015) who reported that, marital status do not influence the adoption of SLARI-promoted grain storage technologies in their study area. Chukwu, *et al.* (2020) revealed that, marital status bore a negative coefficient and was statistically significant at 1%. This means that there was a great difference between married farmers and non-married farmers in terms of technology adoption. Membership of association was found to be positive and significant ($P < 0.01$) in influencing the adoption of solar-powered cold storage technology in the study area, implying that a unit increase in the years of membership increases the likelihood of adoption of solar-powered cold storage technology among vegetable marketers by a factor of 1.2160. This implies that, Members with long



years of cooperative experience will have high level of cooperative spirit and will also participate actively in cooperative business. This agrees with the findings of Bala, *et al.* (2022) who reported in their findings that, membership of cooperative society results showed that most 81.1% of the respondents are members of cooperative. Income was found to be positive and significant ($P < 0.05$) in influencing the adoption of solar-powered cold storage in the study area. This implies that a unit increase in income increases the likelihood of adoption of solar-powered cold storage technology among vegetable marketers in the study areas. This in line with *a priori* expectation because marketers with increased annual income are expected to adopt innovations more than those with lower annual income. This is similar with the finding of Chukwu, *et al.* (2020) who postulated that annual income of the respondents was positive and significant in influencing adoption. This implies that positive relationship exists between the marketers' annual income and their level of adoption of solar-powered cold storage technology.

Table 3: Factors Influencing Adoption of Solar-Powered Cold Storage Technology

Variables	Coef.	Std. Err.	Z	P> z
Age	-.0550169	.031724	-1.73	0.083
Sex	-.4217641	.880612	-0.48	0.632
Marital status	2.208833	.7897366	2.80***	0.005
Household size	.044791	.0470532	0.95	0.341
Educational level	.3329296	.2916136	1.14	0.254
Marketing Experience	.0431887	.0282117	1.53	0.126
Membership status	1.216009	.4401944	2.76***	0.006
Monthly income	2.8706	1.5306	1.87**	0.061
Constant	-7.936026	2.469492	-3.21***	0.001
Log likelihood	-179.96583			
Pseudo R ²	0.0889			

Source: Field Survey, 2023

** = $P < 0.05$,

*** = $P < 0.01$

CONCLUSION AND RECOMMENDATION

The study concluded that majority of vegetable marketers in the study area were young, males married and have acquired a basic education for them to understand and be willing to adopt the technology, marital status, membership of association and annual income were the factors influencing the level of solar powered cold storage technology adoption by the vegetable marketers in the study area. Also, the level of adoption of solar cold storage technology among vegetable marketers was high. The study therefore, recommends that, Government, NGOs and financial institutions should collaborate to provide financial assistance such as low-interest loans, grants, or subsidies to the marketers, Vegetable marketers should partner with solar technology companies to develop affordable cold storage solutions that suit their financial capacities, government and private sector stakeholders should prioritize funding and constructing additional cold storage facilities for vegetable marketers.

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