Journal of Agripreneurship and Sustainable Development (JASD)
www.jasd.daee.atbu.edu.ng; Volume 3, Number 3, 2020
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

FARM LEVEL ASSESSMENT OF POST-HARVEST LOSSES ESTIMATION AND MANAGEMENT OF YAM IN BENUE STATE, NIGERIA

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ABSTRACT
The study measured post-harvest losses of yam in volumetric and monetary terms and the determinants of post-harvest losses (PHLs) management capacities of farmers along diverse activities at the farm level in Benue State, Nigeria for four different production seasons. Using a multistage sampling procedure, 240 yam farmers were sampled and interviewed for the study. Empirical results showed that majority of yam farmers (80.42%) experienced substantial losses, ranging from 20% – 49.9% of their total harvest. Averagely, farmers recorded 43.57% loss of yam tubers on account of environmental and institutional factors especially, the erratic rainfall patterns and lack of improved storage facilities. The post-harvest management index indicated that farmers had the capacities to store, consume or sell about 58.5% of their total annual harvest. The prime causes of such losses were attributed to environmental ($\overline{X}$ = 3.67) and microbiological ($\overline{X}$ = 3.20) factors, duration needed to store yam profitably ($\overline{X}$ = 2.88), mechanical damage ($\overline{X}$ = 2.75), poor marketing ($\overline{X}$ = 2.68), and inappropriate transportation ($\overline{X}$ = 2.65) systems. Further, the degree of PHLs management capacities of the farmers' increased consistently, positively and significantly at $P \leq 0.01$ level of significance, with increase in the age, household size, annual income, access and sources of agricultural credit and the number of PHL management technologies adopted, but rather reduced significantly with years of farming experience and extension contacts. To enhance the post-harvest management competence of farmers in Benue State, the capacities of the farmers should be strengthened to access agricultural information, including geo-informatics, and financial services that can be used in minimizing the incidence of post-harvest losses.

Keywords: Assessment, Farm level, and Management, Post-harvest losses, Yam.

INTRODUCTION

The Sustainable Development Goal 12 (SDG12) of ensuring sustainable food consumption and production patterns recognized interventions in post-harvest losses (PHL) reduction as an important component of the efforts to achieve food security and to realise the full potentials of agriculture. Post-harvest losses of food produce occur at all stages along the commodity value chain. However, focusing on where and how PHLs occur is critical to the understanding of appropriate interventions. This according to Parfitt *et al*. (2010) and Rosegrant *et al*. (2015), PHLs at the farm level, for instance, if not properly surveyed may result in mistargeted interventions in reducing such losses, and that accurate and consistent measurement is an important input when considering measures to reduce losses.

Literature is awash with different methodologies of achieving food security. However, one of the most important pathways to increasing food availability and strengthening food security is by reducing post-harvest losses and food wastes (Action Contre la Faim [ACF], 2014; and Bourne, 2014). Based on the recommendations of Food and Agriculture Organization [FAO] (2011), the first systematic effort to quantify food loss and waste at all levels is an important step in addressing this challenge. Post-harvest food losses are in in fact, amongst the major sources of food insecurity in Nigeria and many developing countries. In the views of Okoedo-Okojie and Onemolease, (2009) and Ansah and Tetteh (2016), unless serious attention is given to PHLs, the possibility of achieving food security will remain a mirage. Goldsmith *et al.* (2015) opined that preventing food loss and increasing production remain the two realistic alternatives by which the world can meet its ever rising food demand. In the views of Chukwunta (2014), PHLs are in fact, one of the greatest problems facing agricultural production in Nigeria. Ostensibly, increased food production can only be actualised by preventing post-harvest losses and this paradigm has the potency to combat hunger, raise income and improve food security and livelihoods of farmers, especially in developing countries (ACF, 2014). Therefore, post-harvest loss in yam can be viewed in terms of the degradation in quantity and quality of yam from harvest to consumption. Such loss entails any change in the availability, edibility, wholesomeness or quality of yam that prevents it from being consumed by people.

Yam is one of the most important tropical root crops second to cassava. In Nigeria, yam is a food security crop among many households (NBS, 2012). Nigeria is the largest producer of yams in the world, followed by Ghana, Cote D'Ivoire, Benin, Togo, and Cameroon (FAO, 2013). At the home front, Benue State is the largest producer of yam in Nigeria. However, statistics show that only 43% of households harvesting yam sell any share of the production (NBS, 2014). This is because of the inability of many yam producers to meet certain market standards both at the local and international markets where the yam produced do not meet the phytosanitary regulations of importing countries due to post-harvest damages. In economic terms, yams do not just serve as the main source of earnings and food consumption, but also as a major employer of labour in Nigeria.

As averred by Verter and Bečvařova (2014), despite the importance of yams to many households, the attention to its production is still questionable, but more worrisome, is the losses incurred in the post-harvest operations due to lack of proper post- harvest processes and empirical information in the operationalization of PHL reduction strategies. This proposition underscores the importance of consistent and reliable methodological measurement of PHL in achieving the goal of reducing PHLs.

Given the significance of yam in the food security equation of Benue State and Nigeria at large, it is imperative to estimate the volume and incidence of post-harvest losses (PHLs) of yam, examine the degree of farmers' effectiveness in the management of postharvest losses and to assess the determinants of post-harvest losses at the farm level in Benue State, Nigeria.

MATERIALS AND METHODS

The Study Area

The study measured post-harvest losses of yam in volumetric and monetary terms and the determinants of PHLs along diverse activities that take place at the farm level in Benue State, Nigeria. Located between Longitude 7° 47' and 10°0' E, and Latitude 6°25' and 8° 8' N in the North-central region of Nigeria, the State occupies a total land mass of 33,955 Km^2 with a population of 5,741,800 people (NBS, 2016 estimate). The 23 Local Government Areas (LGAs) of the State are politically and agriculturally divided into three zones; Zones A, B and C with a total household 413, 156 farm-families (BNARDA, 2005). It is bounded to the North

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www.jasd.daee.atbu.edu.ng; Volume 3, Number 3, 2020
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

by Nasarawa State, Kogi State to the West, Taraba State and the Republic of Cameroun to the East, and to the South by Cross-River and Enugu States.

Sampling Procedure and Sample Size

A multi-stage sampling procedure was employed to select 240 yam farm holders in the State over a span of four years (2015 - 2018). Firstly, all the three (3) agricultural zones were selected but three LGAs were purposively selected from each zone based on the level of yam production. These were Ukum, Gboko and Okpokwu from zones A, B and C, respectively. Furthermore, four (4) communities were sampled from each Local Government Area (LGA) using simple random sampling technique to obtain a total of 12 communities. Lastly, a proportionate random sampling of 5% of the yam farm holders from each of the selected communities was made and requisite information was obtained through questionnaire and oral interviews from the selected 240 farmers.

Analytical Techniques

Data analysis was achieved by the use of descriptive statistics, post-harvest management coefficient (PMC) and multiple regression analysis. The use of post-harvest management coefficient was in addition, to reduce the variability in farm size, and the standardisation of yam tubers.

$$\text{PMC} = \frac{\text{Quantity of yam sold/stored/consumed after harvest} - \text{Quantity lost after harvest}}{\text{Quantity sold/stored/consumed after harvest}} \quad \ldots (1)$$

This coefficient is a proportion with values closed between 0 and 1 ($0 \leq \text{PMC} \leq 1$). PMC was also taken as the main dependent variable in this study, and it measured the extent or degree of effectiveness of a farmer in managing postharvest losses (Ansah *et al*., 2018).

$$\text{PMC} = \beta_0 \sum_{i}^{N} \beta_j X_{ij} + \varepsilon_i \quad \ldots (2)$$

where;

PMC = Post-harvest Management Coefficient, a measure of post-harvest losses. It can also be expressed as percentage of yam lost.

β_0 = constant term

β_j = the regression coefficients to be estimated ($\beta_1 - \beta_{12}$)

X_{ij} = independent variables for the j^{th} farmer($X_1 - X_{12}$)

N = sample size in the range 1 -240

ε_i = error term that accounts for the unmeasured variables

Thus,

$$\text{PMC} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \cdots + \beta_{12} X_{12} + \varepsilon_i \quad \ldots (3)$$

where;

PMC, β_0, and other parameters are as defined in eq. 2.

X_1 = Sex (0 = female; 1 = male),

X_2 = Age (No. of years),

X_3 = Marital status (1 = single; 2 = married; 3 = divorced; 4 = widowed)),

X_4 = Household size (No. of persons per household),

X_5 = Educational status (0 = no formal education; 1 = primary; 2 = secondary; 3 = tertiary),

X_6 = Farm Size (Hectares),

X_7 = Years of farming experience (No. of years),

X_8 = Annual income (₦),

X_9 = Access to agricultural credit (0 = no access; 1 = access),
X_{10} = Sources of credit (1 = personal; 2 = cooperatives; 3 = banks; 4 = others sources),
X_{11} = Number of agricultural extension contacts (no. of visits),
X_{12} = Number of yam PHLs management technologies (No. of PHLs in use)

RESULTS AND DISCUSSION

Estimation of Post-Harvest Losses of Yam in Benue State

The extent of post-harvest losses of yam was estimated as the number of usable yam tubers harvested less the number of tubers wasted or lost over a period of four years (Table 1). The result showed a mean harvest of 1,391 tubers, valued at ₦ 430,400 in 2015, out of which an average number of 572 tubers (₦ 157,610) were recorded as loss, (41.78% loss).

Table 1: Volumetric and Monetary Losses incurred by Yam Farmers in Benue State

	Quantity			
Variables	**Harvested**	**Consumed**	**Sold**	**Lost**
Year 2015:				
Min.	106 (15,000)	20 (3,500)	40 (7,500)	0
Max.	10,000 (2,200,000)	700 (330,000)	5,000 (1,540,000)	5,050 (143,000)
Mean	1,391 (430,400)	138 (38.640)	686 (235,600)	572 (157,610)
Std. Dev.	1,473 (438,625)	99 (45,780)	792 (316,710)	712 (186,030)
Year 2016:				
Min.	0	0	0	0
Max.	12,000 (3,859,000)	1,500 (270,000)	5,200 (2,400,000)	7,500 (1,875,000)
Mean	1,536 (461,840)	139 (32,900)	677 (265,940)	723 (164,510)
Std. Dev.	1,797 (561,300)	129 (34,090)	855 (399,500)	1,005 (214,100)
Year 2017:				
Min.	107 (13,000)	28 (3,500)	20 (2,000)	9 (600)
Max.	15,000 (4,000,000)	2,000 (1,000,000)	7,600 (2,900,000)	5,400 (2,628,000)
Mean	1,566 (493,520)	161 (40,670)	716 (264, 900)	696 (190,400)
Std. Dev.	1,958 (653,250)	172 (76,250)	1,048 (431,800)	902 (311,330)
Year 2018:				
Min.	50 (7,500)	10 (500)	30 (2,000)	7 (5,000)
Max.	20,000 (6,200,000)	2,000 (650,000)	12, 000 (3,450,000)	7,200 (5,200,000)
Mean	1,841 (629,720)	175 (48,670)	918 (341,130)	753 (241,150)
Std. Dev.	2,452 (870,380)	210 (76,450)	1,440 (496,310)	1,078 (485,120)

Note: The values in parenthesis indicate monetary equivalent in Naira
Source: Field Survey, 2019

Similarly, Table 1 revealed that the average of 1,536 tubers was harvested in year 2016 with average usable tubers of 813 (₦399,840) were recorded. However, the average total loss of 723 tubers (₦164,510); an equivalent of 47.12% loss in the quantity of total harvest. The 2017 and 2018 farming seasons recorded marginal appreciation in the volume of yam tubers harvested, and also the quantities that were recorded as losses. The results show an average harvests of 1,566 and 1,841 tubers, valued at ₦493,520 and ₦629720 in 2017 and 2018 farming seasons, respectively. These results further indicate that 696 (₦190,400) and 753 (₦241,150) tubers, representing 44.47 and 40.93% losses, respectively. The average losses over the years was 43.57%, which is considered relatively high, and the reasons for the such quantum of loss were attributed to environmental and institutional factors especially, erratic rainfall patterns and lack of improved storage facilities. For instance, the rate of deterioration of yam is faster at high temperatures. This result agrees with the submission of Atanda *et al.* (2011) that the storage life of certain agricultural products and the amount of loss within a given time are greater at higher temperatures. On the other hand, a working supply chain with efficient storage facilities can lower the amount of food (Trienekens, 2011).

Post-Harvest Losses of Yam

Table 2 shows the result of the percentage losses of yam in Benue State. The result showed that only two farmers (0.83%) recorded less than 20% losses while 99% of yam farmers experienced post-harvest losses ranging from 20 – 70.44%. Detail analysis depicts that majority of yam farmers (80.42%) lost substantial quantities of tubers, ranging from 20 – 49.9% of their total harvest. These statistics negate the findings of Ansah and Tetteh (2016) and Tanye (2016) who reported fewer losses in Ghana. These losses according to the responses were basically induced by environmental, microbiological, storage and mechanical related factors as well as poor marketing and transportation systems. The implications of such losses were that they impact negatively on farmers' productivity and profitability.

Table 2: Cumulative Percentages of PHLs of Yam (percentage [%] of losses /100 tubers)

Loss (tubers)	Frequency	%	Mean	Min	Max
≤19.9	2	0.83	18.38	16.98	19.78
20 – 29.9	19	7.92	26.50	20.08	29.93
30 – 39.9	80	33.33	35.51	30.02	39.95
40 – 49.9	94	39.17	44.80	40.0	49.89
≥50	45	18.75	55.02	50.01	70.44
Total	**240**	**100**	**41.95**	**16.98**	**70.44**

Source: Field Survey, 2019

Post-Harvest Management Capacity

Using the Post-Harvest Management Coefficient (PMC), the index for the management of post-harvest losses was computed (Table 3). PMC measures the extent or degree of effectiveness of a farmer in managing postharvest losses (the larger the value of the coefficient, the greater the farmer's ability to curtail losses and vice versa). With the cut off index of 0.50, index values below this cut off indicate the farmers' poor ability to manage losses. The results showed the mean indices for the four years' period above the cut-off point of 0.50. The results indicated that the PMC rose from 0.554 in 2016 to 0.662 in 2018, indicating that farmers only incurred loss of about 33.8% of their produce in 2018. This may suggest an improvement in the instruments and techniques used in managing post-harvest losses.

Table 3: Postharvest Management Coefficients

Index	2015	2016	2017	2018	Pooled*
PMC	0.588	0.554	0.576	0.622	0.585
Min.	0.277	0.179	0.120	0.135	0.316
Max.	1.000	0.895	0.997	0.973	0.802
Std. Dev.	0.143	0.138	0.148	0.172	0.086

*Cut off index of 0.50 and above indicates increasing level of effective management
Source: Field Survey, 2019

Holistically, the index (Table 3) indicated that yam farmers in Benue State were 0.585 efficient in the management of post-harvest losses. This implies that farmers only have the capacities to store, consumed or sell about 58.5% of their harvest, but incurred losses of about 42% of the total harvest. This result agrees with the submissions of Gernah *et al.* (2013) that postharvest losses of yam in Benue can be as high as 20% – 67%. The quantum of loss recorded is huge compared to the usable proportion of yam tubers harvested. This may be attributed to factors such as farmers' inability to contain bacterial and fungi infestation that result in rotting, biological and environmental processes as well as mechanical damages and rodent attacks during storage.

Causes of Post-Harvest Losses of Yam

Table 4 shows yam farmers' responses to the perceived causes of post-harvest losses experienced on a four point Likert scale (4 = Very Great Extent, 3 = Great Extent, 2 = Less Extent, 1 = No Extent) with a cut-off point of 2.5. The result showed that farmers perceived; $\bar{X}$ = 3.67 'environmental factors', $\bar{X}$ = 3.20 'microbiological factors', $\bar{X}$ = 2.88 'duration needed to store yam profitably', $\bar{X}$ = 2.75 'mechanical damage', $\bar{X}$ = 2.68 'poor marketing system', $\bar{X}$ = 2.65 'inappropriate transportation system' as prime causes of post-harvest losses of yam.

The agreement that post-harvest losses are largely caused by environmental factors ($\bar{X}$ = 3.67) can be adduced to factors such as high temperature, relative humidity, air velocity and atmospheric composition (concentration of oxygen, carbon dioxide, and ethylene), and most recently, the erratic nature of rainfall during the production cycle of yam. This result is corroborated by the findings of Atanda *et al*. (2011) who recognized environmental factors as major cause of post-harvest losses in perishable crops in Nigeria. In consonance with the view of Kader (2013), temperature is the most important factor that influences deterioration of harvested commodities. Similarly, farmers' perception of microbiological processes ($\bar{X}$ = 3.20) such as bacteria and fungi attacks as second rated core cause of post-harvest losses of yam tubers, especially during storage, can be attributed to the absence of appropriate chemicals that could inhibit or minimize the effects of these micro-organisms from causing harm to stored yam. This is in agreement with the findings of Udemezue and Nnabuife (2017) that yam viruses not only reduce tuber yield and quality but also increase the cost of preventive measures.

Table 4: Causes of Post-Harvest Losses of Yam Experienced by Famers (n = 240)

Causes	**Responses**				
	VGE	**GE**	**LE**	**NE**	**Mean**
Environmental factors	106 (44.2)	119 (49.9)	12 (5.0)	3 (1.2)	3.67
Microbiological factors	125 (52.1)	38 (15.8)	77 (32.1)	0	3.20
Duration of storage	12 (5.0)	187 (77.9)	41 (17.1)	0	2.88
Mechanical factors	40 (16.7)	122 (50.8)	55 (22.9)	23 (9.6)	2.75
Poor marketing system	62 (25.8)	69 (28.8)	56 (23.33)	53 (22.1)	2.68
Poor transportation facilities	34 (14.2)	128 (53.3)	39 (16.2)	39 (16.2)	2.65
Biochemical factors	0	75 (31.2)	73 (30.4)	92 (38.3)	1.93
Animals/Insects attacks	4 (1.7)	63 (26.2)	84 (35.0)	89 (37.1)	1.93
Inadequate processing facilities	21 (8.8)	39 (16.2)	59 (24.6)	121 (50.4)	1.83
Theft of yam tubers	0	68 (28.3)	64 (26.7)	108 (45.0)	1.83
Inadequate storage facilities	14 (5.8)	44 (18.3)	52 (21.7)	130 (54.2)	1.76
Chemical factors	0	48 (20.0)	82 (34.2)	110 (45.8)	1.74
Fire outbreak	0	38 (15.8)	39 (16.2)	163 (67.9)	1.48
Mean score ($\bar{X}$)					**2.50**

Note: Values in parenthesis indicate percentages; VGE = Very Great Extent, GE = Great Extent, LE = Less Extent, NE = No Extent.
Source: Field Survey, 2019

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ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

A good proportion of farmers' perception of causes of post-harvest losses of yam were rooted in the duration required to store yam profitability ($\overline{X}$ = 2.88) and mechanical damage to yam tubers ($\overline{X}$ = 2.75) during harvest, handling, transportation and packaging. The recognition of mechanical factors as principal cause of post-harvest losses of yam has implication for the harvesting processes where greater percentages of these damages are incurred. This result agrees with the findings of Atanda *et al.* (2011) and Ansah and Tetteh (2016) who identified mechanical injuries as key causes of post-harvest losses of yam. Attempts to reduce these losses lies in careful and appropriate measures to minimize bruises, punctures and scratches to the tubers. This is necessary because mechanical injuries provide sites for pest attacks and accelerated physiological losses. Similarly, techniques such as the general principles of extending shelf life of yam through varietal selection, and sorting of quality tubers for storage can minimize losses during storage.

The nexus of poor marketing and transportation systems as critical causes of PHLs in yam can be explained by the fact that yam marketing for instance, is done when tubers are fresh and mostly a distance away from the point of production. Due to the bulky and perishable nature of yam, they require appropriate transportation system to retain the market value. However, due to poor road network and appropriate (well ventilated) vehicles and untimeliness of voyage, appreciable level of losses could be recorded in these processes. This result is in consonance with the findings of Opera (2003) and Chukwunta (2014) who advocated the used of ventilated vehicles and transportation.

Determinants of Yam Farmers' Post-Harvest Losses Management Capacity

The determinants of post-harvest losses at farm level and the farmers' capacities to manage such losses are presented in Table 5. Results showed that the level of PHLs management capabilities of the farmers' increased consistently, positively and significantly at 1% level of significance, with increase in the age, household size, farm size, annual income, access and sources of agricultural credit and the number of PHL management technologies at the disposal of the farmers.

Table 5: Determinants of Yam Farmers' Post-Harvest Losses Management Capacity

Variables	**β**	**Std. error**	**t-value**	**Sig.**
Constant	-11.595***	1.299	-8.925	0.000
Sex (X_1)	-0.095	0.124	-0.765	0.445
Age (years) (X_2)	0.139***	0.039	3.577	0.000
Marital status (X_3)	-0.010	0.057	-0.166	0.868
Household size (No.) (X_4)	0.580***	0.053	10.853	0.000
Educational attainment (X_5)	0.017	0.044	0.390	0.697
Farm size (ha) (X_6)	0.573***	0.145	3.959	0.000
Years of farming experience (X_7)	-0.151***	0.035	-4.275	0.000
Annual income (X_8)	3.537***	0.214	16.511	0.000
Access to credit (X_9)	0.312***	0.109	2.862	0.005
Sources of credit (X_{10})	0.398***	0.045	8.801	0.000
No. of extension contacts (X_{11})	-0.968***	0.129	-7.479	0.000
PHLs management technologies (X_{12})	0.387***	0.032	11.934	0.000
R^2	0.996			
R^2 Adjusted	0.986			
F-Statistics	4345***			

***significance level at 1%.
Source: Field Survey, 2019

Table 5 by implication, as the farmers' age and household size increased by single unit, they become valuable assets to increase the farmers' ability to manage losses (by 13.9 and 58.0%, respectively) through effective coordination and mobilization of family members to respond appropriately to PHLs incidences. This result is contrary to the findings of Ansah and Tetteh (2016) who averred that age and household size impact negatively on post-harvest management ability. Similarly, income and access and source of agricultural credit can aid farmers in securing, financially, the needed management protocols to tackle PHLs timely and effectively, hence the positive (0.387) effect of the number of PHLs management technologies on the farmer's management capacity.

Conversely and contrary to *a priori* expectations, years of farming experience and the number of extension contacts. The negative coefficient of experience suggests that farmers who had long years of farming experience rather had problems managing losses. Ordinarily, the effect of years of farming experience is expected to boost farmers' productivity and post-harvest management capacities until it gets to a stage in life where declining output sets in with successive addition. At younger ages, farmers have more strength and zeal to undertake more effective management strategies that reduce postharvest losses. As the farmer advances in age, the ability to effectively manage postharvest losses reduces. This result is in consonance with the finding of Tanye (2016) and Adejo (2017) who asserted little or no access to information on improved post-harvest management technologies. Similarly, the negative coefficient of extension contacts suggests that extension contacts rather impacted negatively on PHLs management. This can be explained in terms of the information received from extension agents. Considering the causes of PHLs experienced over the years under study, any meaningful information should address and build the capacities of farmers in dealing with the current challenges of weather vagaries and microbiological effects that exacerbate yam PHLs.

CONCLUSION AND RECOMMENDATIONS

Knowing the proportion of post-harvest is fundamental in managing such losses. The study attempts to measure the volumetric and monetary post-harvest losses of yam and the determinants of PHLs management capacities of farmers at the farm level in Benue State, Nigeria. The concomitant effect of post-harvest losses was that it leads to reduction in farmers' income, waste of agricultural resources, and can results in the long-run, to higher food prices and food insecurity in an agriculturally inclined society.

Based on the empirical evidence, the study showed that majority of yam farmers' experienced substantial losses of yam tubers (20 – 49.9%) during and after harvest. On the average, farmers recorded 43.57% loss of yam tubers on account of environmental and institutional factors especially, the erratic rainfall patterns and poor marketing and transportation systems. However, farmers exhibited post-harvest management competence by storing, consuming or selling 58.5% of their total annual harvest. The farmers' capacities to manage post-harvest losses is enhanced with increase in age, household size, annual income, access and sources of agricultural credit and the number of PHLs management technologies as prime determinants. To enhance the post-harvest management capabilities of farmers in Benue State, it was recommended that:

1. There is need to strengthen farmer's capacities to unable them access agricultural information, including weather and market information, financial services.
2. Huge investments in yam post-harvest losses management are needed in minimizing the incidence of post-harvest losses.

3. Finally, effective management of post-harvest losses at the farm level is a cardinal measure to abate consequences of PHLs.

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