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Farmers' Knowledge, Compliance with Post-Harvest Handling Standard Operating Procedures and State-Level Variation in Sweet Potato Production in North-Western Nigeria

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Abstract
Post-harvest losses remain a major constraint on food security and farm incomes in Nigeria, where a substantial share of harvested sweet potato is lost between the field and the market through careless harvesting, inadequate curing, poor storage and unsuitable transportation. This study examined farmers' knowledge of recommended post-harvest handling practices, assessed their level of compliance with Standard Operating Procedures (SOPs), estimated the magnitude of post-harvest losses, and compared compliance between Kano and Jigawa states. A cross-sectional survey design was adopted and a multistage sampling procedure was used to administer structured questionnaires to sweet potato farmers in ten local government areas, yielding 418 valid responses (210 in Kano and 208 in Jigawa). Data were analysed using descriptive statistics, a weighted compliance index and an independent samples t-test supported by Cohen's d and Levene's test. Farmers possessed a moderate but uneven level of knowledge, strongest in the experience-based harvesting and curing components and weakest for refrigerated transport and technically demanding storage practices. The overall weighted compliance index was 50.22%, indicating that only about half of the recommended procedures were being implemented; compliance was highest for harvesting (57.58%) and lowest for transportation (31.44%), and 52.9% of farmers reached the 50% compliance threshold. Mean post-harvest loss was 37.50% of output, valued at approximately NGN 89.3 million, with harvesting and storage accounting for the largest absolute losses. Compliance was significantly higher in Kano (53.85%) than in Jigawa (46.45%) ($t = 5.648$, $df = 416$, $p < 0.001$; Cohen's $d = 0.552$). Targeted, demonstration-based extension emphasising transportation and storage, and more intensive support for Jigawa, are recommended.
Keywords: Compliance, knowledge, post-harvest losses, standard operating procedures, sweet potato

Introduction

Sweet potato (Ipomoea batatas) is among the most important root crops in the world, contributing to food security, nutrition and income generation, particularly in developing countries. The crop is valued for its adaptability to marginal soils, its short growing cycle and its high nutritional content, including the high beta-carotene content of orange-fleshed varieties, which helps to address vitamin A deficiency. Nigeria is one of the leading producers of sweet potato in Africa, with millions of smallholder farmers cultivating the crop for both subsistence and commercial purposes, and it serves as an affordable source of energy for low-income

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households (Oluwasani, Adeyemi, Nebechi, & Ichaba, 2021; Pawlak & Kolodziejczak, 2020).

Despite this importance, the economic contribution of sweet potato production in Nigeria is heavily constrained by post-harvest losses. Post-harvest losses refer to the quantitative and qualitative reduction in produce occurring between harvest and consumption, and they arise at harvesting, curing, transportation, storage and marketing. In Nigeria, losses in root and tuber crops are high because of inadequate infrastructure, poor storage facilities, inefficient transportation and limited access to modern preservation technologies, with estimates suggesting that up to 40% of harvested sweet potato output is lost before it reaches the consumer (Adelani, Olanrewaju, & Ugbaja, 2021; Khan, Ali, & Zubair, 2021; World Bank, 2019). Because sweet potato is bulky, has a high moisture content and a thin, easily damaged periderm, it is particularly susceptible to mechanical injury, sprouting, dehydration and microbial deterioration during handling (Kumar, Jain, & Gupta, 2019; Ugonna, Jolaoso, & Onwualu, 2013).

Standard Operating Procedures (SOPs) for post-harvest handling have been developed to minimise these losses. They prescribe recommended practices for each stage of the handling chain, including the use of appropriate harvesting tools, protection of harvested roots from direct sunlight, curing under controlled temperature and humidity before storage, the use of ventilated storage structures and careful loading and aeration during transportation. Evidence from across sub-Saharan Africa, however, suggests that adherence to such procedures among smallholders is weak, and that the reduction of losses depends not only on what farmers know but on whether that knowledge is translated into practice. This distinction between knowledge and behaviour is central to the diffusion of innovations framework, in which awareness and knowledge constitute only the initial stages of the innovation-decision process, and to the value chain perspective, which holds that the performance of the chain as a whole is determined by its weakest node (Porter, 1985; Rogers, 2003).

While a number of studies have estimated the magnitude of post-harvest losses in Nigeria, fewer have measured farmers' knowledge and their actual compliance with recommended procedures using a structured, component-level instrument, and fewer still have examined whether compliance differs systematically between producing states. Such sub-national comparison matters because aggregate zonal or national statistics can conceal substantial disparities in infrastructure, market access and extension coverage, and because interventions are designed and delivered at state level. The North-West geopolitical zone, where sweet potato production is concentrated, therefore provides an appropriate setting in which to examine these questions.

This study was accordingly guided by three specific objectives: to determine the level of knowledge of sweet potato farmers regarding post-harvest handling practices; to assess the level of farmers' compliance with the SOPs for sweet potato post-harvest handling; and to compare the level of SOP compliance between Kano and Jigawa states. The magnitude and distribution of post-harvest losses were also estimated in order to establish the economic significance of the compliance shortfall identified. The study tested the null hypothesis that there is no significant difference in the mean SOP compliance index between farmers in Kano and Jigawa states.

Methodology

The study was conducted in Kano and Jigawa states, two leading sweet potato-producing states in the North-West geopolitical zone of Nigeria. The zone lies within the Sudan and Northern Guinea Savannah vegetation belts and is characterised by low annual rainfall of between 50 and 120 cm, mean annual temperatures of 25 to 30 degrees Celsius and a long dry season of six to nine months. Its predominantly agrarian population depends on crops such as sweet potato, maize, millet, groundnut, cotton and cassava, and sweet potato is among

the most widely produced crops among rural households in the area.

A cross-sectional survey design was adopted within a quantitative analytical framework, since the study sought to measure knowledge, compliance and losses at a single point in time across a large and geographically dispersed farming population. A multistage sampling procedure was employed. In the first stage, Kano and Jigawa states were purposively selected on the basis of the intensity of sweet potato production, the remaining states of the zone being excluded on grounds of insecurity. In the second stage, five local government areas were purposively selected from each state, namely Bichi, Bagwai, Shanono, Tsanyawa and Ghari in Kano state, and Ringim, Taura, Babura, Kazaure and Roni in Jigawa state. In the third stage, sweet potato farmers were randomly selected from the rural communities of each local government area.

The total population of sweet potato farmers in the two states was 7,789. Applying the Taro Yamane formula at a 95% confidence level and a 5% margin of error yielded a minimum required sample of 381 respondents. To allow for non-response and incomplete returns, 450 questionnaires were administered, of which 418 were completed and found valid for analysis, representing a response rate of 92.9%. The final sample comprised 210 respondents in Kano and 208 in Jigawa.

Primary data were collected during the harvest period over a period of eight weeks by three trained enumerators using a structured questionnaire administered in Hausa. The instrument comprised five sections covering socio-economic characteristics, knowledge of post-harvest handling measured on a five-point Likert scale (27 items), compliance with SOPs measured through binary responses (32 items), self-reported post-harvest losses, and farm and institutional characteristics. Content validity was established through expert review and an explicit objective-to-item mapping, and internal consistency was assessed using Cronbach's alpha, which returned coefficients of 0.78 for the harvesting component, 0.82 for curing, 0.75 for transportation, 0.79 for storage and 0.81 for the overall knowledge scale, all exceeding the 0.70 threshold generally regarded as acceptable in social science research (Field, 2013; Nunnally & Bernstein, 1994).

Three analytical tools were applied. Knowledge was analysed using descriptive statistics. Because Likert-scale responses constitute ordinal data, the median, mode and interquartile range are reported as the appropriate measures of central tendency and dispersion rather than the mean and standard deviation, which assume interval-level measurement (Field, 2013).

Compliance was measured using a weighted compliance index. The percentage of recommended practices complied with was first computed for each of the four handling components, and the component scores were then combined using weights reflecting the relative contribution of each component to total losses in the empirical literature: harvesting 0.30, curing 0.25, storage 0.25 and transportation 0.20. The index was computed as:

Compliance Index (%) = (Harvesting x 0.30) + (Curing x 0.25) + (Storage x 0.25) + (Transportation x 0.20)

A farmer scoring 50% or above on the index was classified as compliant, and one scoring below 50% as non-compliant. Post-harvest losses were estimated from farmers' self-reported quantities harvested and quantities lost at each handling stage, expressed as a percentage of the quantity harvested and disaggregated by stage.

The comparison between the two states was made using an independent samples t-test on the mean weighted compliance index, with Group 1 (Kano) n = 210 and Group 2 (Jigawa) n = 208, degrees of freedom of 416, a two-tailed significance level of 0.05 and a critical value of 1.966. The hypotheses tested were that there is no significant difference in mean SOP compliance between the two states (H0) against the alternative that a

significant difference exists (H1). Three supplementary procedures strengthened the test: Levene's test was used to verify the assumption of equality of variances, Cohen's d was computed to establish the practical magnitude of any difference, with values of 0.2, 0.5 and 0.8 interpreted as small, medium and large effects respectively, and the four component scores were compared separately between the states in order to locate the specific sources of any overall difference. All analyses were performed using IBM SPSS Statistics version 26.

Results and Discussion

Socio-economic Characteristics of Respondents

The socio-economic characteristics of the sampled farmers are presented in Table I. These descriptive patterns provide the context within which the knowledge and compliance results that follow should be interpreted.

Table I: Socio-economic characteristics of respondents

Variable	Frequency	Percentage (%)
Age (years)		
30 or below	101	24.2
31 to 40	123	29.4
41 to 50	109	26.1
51 to 60	61	14.6
Above 60	24	5.7
Sex		
Male	403	96.4
Female	15	3.6
Marital status		
Married	279	66.7
Single	84	20.1
Widowed	39	9.3
Divorced	16	3.8
Educational attainment		
Primary	165	39.5
Qur'anic	117	28.0
Adult education	92	22.0
Secondary	26	6.2
Tertiary	18	4.3
Farming experience (years)		
0 to 9	154	36.8
10 to 19	98	23.5
20 to 29	74	17.7
30 to 39	68	16.3
40 to 49	24	5.7
Cooperative membership		
Member	116	27.8

Non-member	302	72.2
Type of labour		
Manual	347	83.0
Mechanised	71	17.0
Total	**418**	**100.0**

Mean age = 39.96 years (SD = 12.62); mean years of formal education = 4.68 (SD = 3.98); mean farming experience = 17.64 years (SD = 12.91); mean household size = 9.87 (SD = 2.76); mean total farm size = 2.79 ha (SD = 2.11); mean sweet potato farm size = 1.54 ha (SD = 1.34). Source: Field Survey, 2024.

The farming population was predominantly middle-aged, with a mean age of 39.96 years and 55.5% of respondents falling within the 31 to 50-year bracket, and it was overwhelmingly male (96.4%). The strong male dominance reflects the socio-cultural context of the study area, where field-based commercial crop production and the marketing of produce are undertaken mainly by men, while the agricultural roles of women concentrate on subsistence activities and household-level processing (FAO, 2021). Most respondents were married (66.7%), which implies the availability of household labour for the labour-intensive operations of harvesting, curing and handling.

Formal education was generally low. The largest group had only primary education (39.5%), followed by Qur'anic (28.0%) and adult education (22.0%), while only 10.5% had attained secondary or tertiary education, and the mean number of years of formal schooling was 4.68. This educational profile has a direct bearing on the delivery of post-harvest information, which is more likely to be understood and acted upon when communicated through practical demonstration in the local language than through written material. Farming experience was widely spread, with 39.7% of respondents having twenty or more years of experience and a mean of 17.64 years, indicating a farming population with considerable accumulated practical knowledge. Only 27.8% belonged to a cooperative society, and the great majority (83.0%) relied on manual labour. The heavy reliance on manual operations is directly relevant to post-harvest outcomes, since manual digging and handling raise the risk of mechanical damage to sweet potato roots where appropriate tools and techniques are not used.

Farmers' Knowledge of Post-Harvest Handling Practices

Farmers' knowledge of recommended post-harvest handling practices, measured on a five-point Likert scale across the four components of harvesting, curing, transportation and storage, is presented in Table II. The response distributions are expressed as percentages, and the median, mode and interquartile range are reported for each item.

Table II: Farmers' knowledge of post-harvest handling practices

S/N	Knowledge item	SD	D	N	A	SA	Md	Mo	IQR
	Harvesting component								
1	Harvest using sharp sticks, machetes or hand hoes	12	12	5	24	48	A	SA	2
2	Attention is needed to prevent mechanical damage	5	5	9	28	53	SA	SA	1
3	Harvest within 3 to 8 months depending on variety	10	8	3	30	50	A	SA	1

4	Roots can be harvested piecemeal over months	6	11	17	37	29	A	A	2
5	Protect roots from direct sunlight during harvest	2	10	4	31	53	SA	SA	1
6	Low yields result if harvested too early or too late	3	11	3	36	48	A	SA	1
7	Remove vines 2 to 4 days prior to harvesting	13	25	18	19	25	N	D	2
	Curing component								
8	Curing enhances the lifespan of harvested roots	6	8	0	33	52	SA	SA	1
9	Curing before storage reduces deterioration	10	12	0	27	51	SA	SA	1
10	Curing should be done before storage	8	14	3	26	50	A	SA	1
11	No need to wash sweet potatoes before curing	4	8	0	36	53	SA	SA	1
	Transportation component								
12	Refrigerated transport preserves quality	66	22	2	6	4	SD	SD	1
13	Transport is difficult and costly due to poor roads	9	16	6	23	47	A	SA	2
14	Transport is difficult due to poor storability	12	16	3	32	37	A	SA	3
15	Transport is difficult due to bulkiness of product	14	15	0	33	38	A	SA	3
16	Transport is difficult due to state taxes	23	13	7	26	31	A	SA	3
17	Vehicle breakdown encourages deterioration	19	24	4	35	18	A	A	2
18	Bad roads accelerate deterioration	44	24	2	25	6	D	SD	3
	Storage component								
19	Store in a cool, dark and dry place	14	23	11	19	33	A	SA	3
20	Avoid direct sunlight or heat during storage	8	8	2	25	56	SA	SA	1
21	Use pit or clamp stores to keep roots fresh	12	18	6	29	35	A	SA	3
22	Roots can be stored long-term like grain crops	6	21	10	32	31	A	A	3
23	Room-temperature storage loses 10 to 15% in two weeks	31	21	9	18	20	D	SD	3
24	Use modern storage facilities for long storage	16	24	2	25	33	A	SA	3

25	Check roots regularly during storage	6	23	0	33	38	A	SA	3
26	Store in a well-ventilated area	7	20	2	33	38	A	SA	3
27	Sort damaged roots before storage	18	24	4	30	24	A	A	2

SD = Strongly Disagree, D = Disagree, N = Neutral, A = Agree, SA = Strongly Agree. Figures under the response categories are percentages. Md = median; Mo = mode; IQR = interquartile range. Source: Field Survey, 2024.

Farmers demonstrated the strongest knowledge in the harvesting and curing components, where most items recorded a median response of Agree or Strongly Agree. The highest-rated items were the need to protect harvested roots from direct sunlight (item 5, median and mode Strongly Agree, with 84% of respondents agreeing or strongly agreeing) and the need to prevent mechanical damage during harvesting and handling (item 2, median Strongly Agree, 81% agreement). These are practices whose consequences are immediate and directly observable: exposure to the sun causes visible wilting and deterioration within hours, while bruises and cuts provide entry points for pathogens and accelerate rotting. Farmers have learned these lessons through direct observation and economic loss, and their knowledge is reinforced experientially each season (Eze, Olufemi, & Ogunwande, 2023; Kumar, Jain, & Gupta, 2019).

Knowledge of curing was similarly well established. Farmers broadly agreed that curing enhances the shelf life of harvested roots (item 8) and reduces deterioration before storage (item 9), both recording a median and mode of Strongly Agree, and that washing before curing is unnecessary (item 11). The one clear exception among the early items was the removal of vines two to four days prior to harvesting (item 7), which recorded a median of Neutral and a mode of Disagree, indicating genuine uncertainty about a specific agronomic practice whose rationale, the toughening of the periderm before lifting, is not directly observable to the farmer.

Knowledge was markedly weaker in the transportation component and in the more technically demanding storage items. The lowest-rated item on the entire scale was the proposition that transporting sweet potato in a refrigerated vehicle preserves quality (item 12), which recorded a median and mode of Strongly Disagree, with 66% of respondents strongly disagreeing and only 10% expressing any level of agreement. The recognition that bad roads accelerate deterioration (item 18) also recorded a median of Disagree, with 68% of respondents disagreeing or strongly disagreeing. These low scores are consistent with the infrastructural realities of the study area, where cold-chain transport is effectively unavailable, and farmers move produce by motorcycle, wheelbarrow and open vehicle over relatively short distances. Where a practice has never been observed, its benefits cannot be learned experientially, and the resulting knowledge gap reflects a disconnect between technical recommendations generated in research settings and the conditions under which smallholders actually operate (Amin, Kabir, & Rahman, 2021; McKinnon, 2006).

The same pattern held within the storage component. Farmers were confident about practices that are simple and visible, such as avoiding direct sunlight or heat during storage (item 20, median and mode Strongly Agree, 81% agreement), but weak on those requiring technical understanding, most notably the recognition that produce held at room temperature can lose 10 to 15% of its weight within two weeks (item 23), which recorded a median of Disagree. Physiological weight loss through respiration and transpiration is gradual and largely invisible, and is therefore unlikely to be learned without instruction. It is also notable that the interquartile range was 3 for eleven of the sixteen transportation and storage items, compared with 1 or 2 for every harvesting and curing item, indicating that opinion on the technical items was not merely low but widely

dispersed: farmers do not share a common understanding in these areas in the way that they do for harvesting and curing.

Taken together, the results indicate that sweet potato farmers in the study area possess a moderate overall level of knowledge of post-harvest handling that is unevenly distributed across the four components, being strongest for harvesting and curing and weakest for transportation and technical storage. This has a direct implication for the design of extension programmes: messages that reiterate the basic principles of careful harvesting and curing address knowledge that farmers already hold, whereas the substantive gaps lie in the transportation and storage components, which is precisely where extension effort should be concentrated (Eze et al., 2020).

Compliance with Post-Harvest Handling Standard Operating Procedures

Farmers' actual compliance with the recommended practices, measured through binary responses to thirty-two standard operating procedure items, is presented in Table III. Each item records whether the respondent practises the recommended behaviour.

Table III: Farmers' compliance with post-harvest handling SOPs

S/N	Compliance practice	Yes	%	No	%
	Harvesting component				
1	Harvest using appropriate tools to avoid wounding	257	61	161	39
2	Harvest within the recommended 3 to 8 month window	241	58	177	42
3	Avoid wounding roots during harvest with sharp tools	223	53	195	47
4	Harvest at once rather than occasionally	245	59	173	41
5	Shield roots from direct sunlight during harvest	243	58	175	42
6	Avoid harvesting too early or too late	252	60	166	40
7	Cut off vines 2 to 4 days prior to harvesting	230	55	188	45
8	Harvest when the leaves turn yellow	239	57	179	43
9	Sort out mechanically damaged roots during harvesting	236	56	182	44
	Curing component				
10	Remove foliage 2 to 4 days before harvesting	235	56	183	44
11	Subject roots to 25 to 30 degrees Celsius during curing	231	55	187	45
12	Subject roots to 90 to 95% relative humidity during curing	221	53	197	47
13	Allow roots to cure for 4 to 7 days	227	54	191	46
14	Allow the skin to toughen during curing	220	53	198	47
15	Allow wounds on the roots to heal during curing	223	53	195	47
16	Wash the harvested sweet potato before curing	221	53	197	47
17	Remove dangling roots on the harvested produce	219	52	199	48
	Transportation component				
18	Keep roots under shade before transportation	129	31	289	69

19	Transport with the heaviest roots at the bottom	122	29	296	71
20	Avoid filling sacks to maximum level during transport	146	35	272	65
21	Use crates or boxes during transportation	126	30	292	70
22	Provide good aeration during transportation	124	30	294	70
23	Transport quickly after harvesting to the curing site	138	33	280	67
24	Transport roots in a refrigerated vehicle	135	32	283	68
	Storage component				
25	Use pit and clamp stores to keep roots fresh	212	51	206	49
26	Store roots long-term like grain crops	221	53	197	47
27	Use a modern storage facility for long-term storage	222	53	196	47
28	Store in a cool, dark and dry place	212	51	206	49
29	Store within temperatures of 55 to 60 degrees Fahrenheit	237	57	181	43
30	Check roots regularly during storage	219	52	199	48
31	Avoid direct sunlight or heat during storage	215	51	203	49
32	Store in a well-ventilated area	231	55	187	45

Source: Field Survey, 2024.

Table III reveals a clear and consistent pattern. Compliance was highest for the harvesting practices, where it ranged from 52 to 61%, with the strongest adherence recorded for the use of appropriate harvesting tools to avoid wounding (61%) and the avoidance of premature or delayed harvest (60%). Curing compliance was moderate and tightly clustered between 52 and 56%, and storage compliance was similarly moderate, ranging from 51 to 57%. The transportation component recorded by far the lowest compliance, with every item complied with by fewer than 36% of respondents. The weakest single practices in the entire instrument were transporting with the heaviest roots at the bottom (29%), providing good aeration during transportation (30%) and using crates or boxes rather than sacks (30%).

Two features of this pattern deserve emphasis. First, compliance was consistently lower than knowledge for the harvesting and curing items. For example, 84% of respondents agreed or strongly agreed that harvested roots should be shielded from direct sunlight, yet only 58% reported actually doing so; while 85% recognised the value of curing, only 53 to 56% complied with the specific curing protocols. This confirms the existence of a knowledge-behaviour gap in which awareness does not translate automatically into practice (Rogers, 2003). Second, the transportation component was weak on both dimensions simultaneously: farmers neither knew the recommended practices nor implemented them. Low knowledge and low compliance therefore reinforce one another in transportation, whereas in harvesting and curing the binding constraint lies not in awareness but in the resources, tools and time required to act on what is already known.

Weighted Compliance Index

To provide a single integrated measure of adherence, the four component scores were combined into the

weighted compliance index using the weights established in the methodology. The component means, their standard deviations and the resulting overall index are presented in Table IV.

Table IV: Component and overall weighted compliance scores

Component (weight)	Mean compliance (%)	Standard deviation
Harvesting (0.30)	57.58	20.32
Curing (0.25)	53.74	20.04
Storage (0.25)	52.90	21.12
Transportation (0.20)	31.44	19.53
Weighted compliance index	**50.22**	**13.89**

Source: Field Survey, 2024.

The mean weighted compliance index was 50.22% with a standard deviation of 13.89, confirming that the post-harvest system in the study area operates at only about half of its recommended potential. Compliance was highest for harvesting (57.58%), followed by curing (53.74%) and storage (52.90%), and was markedly lowest for transportation (31.44%). Applying the 50% threshold defined in the methodology, 221 respondents (52.9%) were classified as compliant and 197 (47.1%) as non-compliant, as shown in Table V.

Table V: Distribution of SOP compliance status

Compliance status	Frequency	Percentage (%)
Compliant (50% and above)	221	52.9
Non-compliant (below 50%)	197	47.1
Total	**418**	**100.0**

Source: Field Survey, 2024.

The near-even split of the sample around the compliance threshold is itself informative: the study area contains no dominant group of consistently good or consistently poor performers, but rather a population clustered closely around the halfway mark, with a relatively modest standard deviation of 13.89 percentage points. This suggests that the constraints on compliance are systemic and widely shared rather than confined to a disadvantaged minority.

The compliance profile also mirrors the structure of the underlying practices. Compliance was highest for the harvesting practices, which are embedded in accumulated traditional knowledge, require no purchased input beyond an appropriate hand tool and produce immediately visible consequences when neglected. It was lowest for transportation, where the recommended practices- crates and boxes in place of sacks, cushioning, controlled loading and adequate aeration- all require either capital outlay or control over a vehicle that most smallholders do not own. Curing and storage occupy an intermediate position, since the principles are understood but the recommended conditions, a controlled temperature range of 25 to 30 degrees Celsius and relative humidity of 90 to 95%, are difficult to achieve without purpose-built structures under the ambient conditions of the Sudan Savannah.

Because post-harvest handling is a sequential process, the transportation figure of 31.44% carries greater weight than its numerical share of the index suggests. The quality of produce at each stage depends on the cumulative treatment received at all preceding stages, so careful harvesting and proper curing cannot prevent losses if the produce is subsequently bruised, overheated or crushed in transit. In the language of value chain

analysis, transportation is the weakest node in the chain, and the returns to improving practice at the earlier nodes are therefore capped by it (Porter, 1985). This finding argues for an integrated approach to post-harvest management in which transportation is treated as a priority in its own right, rather than for piecemeal interventions directed at individual stages.

Estimation of Post-Harvest Losses

The economic significance of the compliance shortfall is established by the loss estimates. Across the 418 respondents, a total of 905,676 kg of sweet potato was harvested, of which 336,649 kg was lost, giving a mean overall post-harvest loss rate of 37.50% of output. The estimated value of these losses was approximately NGN 89.3 million, or a mean of about NGN 213,721 per farmer. Table VI disaggregates the losses by handling stage.

Table VI: Post-harvest losses by handling stage

Stage	Mean loss (kg)	Total loss (kg)	Loss rate (%)
Harvesting	280.8	117,365	13.09
Curing	178.8	74,718	8.30
Storage	232.2	97,056	10.85
Transportation	113.7	47,510	5.25
Total	**805.4**	**336,649**	**37.50**

Source: Field Survey, 2024.

Harvesting accounted for the largest share of losses at 13.09% of output, followed by storage (10.85%), curing (8.30%) and transportation (5.25%). The loss figures must be read alongside the compliance results, since the two do not rank in the same order. Although transportation recorded by far the lowest compliance, it accounts for the smallest absolute loss, because the volumes moved per trip are small and the distances between farm and market are short, so poor practice translates into modest absolute quantities. Conversely, harvesting and storage involve the entire crop and generate the greatest absolute losses even at moderate levels of compliance. This distinction matters for the prioritisation of interventions. Reducing losses requires attention both to the stage where practice is poorest, namely transportation, and to the stages where the largest volumes and therefore the largest absolute losses arise, namely harvesting and storage. A programme that concentrated exclusively on transportation because it is the weakest link would address only about one seventh of the physical loss, while one that ignored transportation would leave the chain's binding constraint untouched.

Two qualifications should be noted. First, the loss estimates are based on farmers' self-reported quantities and are therefore subject to recall and estimation error, so they should be interpreted as indicative of the magnitude and relative distribution of losses rather than as precise physical measurements. The internal consistency of the pattern, with losses concentrated at the high-volume harvesting and storage stages, nevertheless lends credibility to the overall picture. Second, the overall loss rate of 37.50% is broadly consistent with the range documented for root and tuber crops in sub-Saharan Africa and with Nigerian estimates for sweet potato specifically, which converge on figures of between 30 and 50% (Adelani et al., 2021; Khan et al., 2021; Sekiya et al., 2020). This agreement with the wider literature strengthens confidence in the validity of the estimate and confirms that post-harvest loss in the study area constitutes a substantial and policy-relevant drain on farm incomes and national food availability.

Comparison of SOP Compliance Between Kano and Jigawa States

The third objective compared the level of SOP compliance between the two states. The group statistics for the

weighted compliance index are presented in Table VII and the results of the independent samples t-test in Table VIII.

Table VII: Group statistics for the compliance index by state

State	N	Mean (%)	Std. deviation	Std. error mean
Kano	210	53.85	13.15	0.908
Jigawa	208	46.45	13.64	0.946

Source: Field Survey, 2024.

Table VIII: Independent samples t-test of compliance between Kano and Jigawa states

Test	t	df	Sig. (2-tailed)	Mean diff.	95% CI	Cohen's d
Equal variances assumed	5.648	416	0.000	7.40	4.83 - 9.98	0.552

Levene's test: F = 0.263, p = 0.609 (equal variances assumed). Source: SPSS output from Field Survey data, 2024.

Mean compliance was higher in Kano (53.85%) than in Jigawa (46.45%), a difference of 7.40 percentage points. Levene's test for equality of variances was not significant (F = 0.263, p = 0.609), so equal variances were assumed. The calculated t-statistic of 5.648 exceeds the critical value of 1.966, and the difference is statistically significant at the 1% level (t = 5.648, df = 416, p < 0.001), with a 95% confidence interval for the difference of 4.83 to 9.98 percentage points. The null hypothesis of no significant difference in mean SOP compliance between the two states is therefore rejected.

The effect size (Cohen's d = 0.552) indicates that the difference is not merely statistically significant but of medium practical magnitude. Since the confidence interval excludes zero by a comfortable margin and its lower bound is itself close to five percentage points, the direction and material importance of the gap are established with reasonable precision. In the context of loss reduction, a difference of this order translates into a substantial divergence in the volume of produce lost and in the economic returns realised by farmers in the two states.

The advantage of Kano was consistent across every component of the index. Kano recorded higher compliance than Jigawa for harvesting (62.1% against 53.0%), curing (56.0% against 51.4%), storage (57.2% against 48.6%) and transportation (34.8% against 28.0%), and a considerably higher proportion of compliant farmers overall (65.7% against 39.9%). The gap was widest in the harvesting and storage components, at 9.1 and 8.6 percentage points respectively, and narrowest in curing at 4.6 percentage points. The consistency of the advantage across all four components indicates a general difference in the conditions under which farming is conducted in the two states rather than a deficiency in any single practice.

Several contextual factors provide a plausible explanation. Kano possesses more developed agricultural infrastructure, a denser network of extension services and a greater presence of research and development institutions, and it has historically been a hub for agricultural commerce and innovation in Northern Nigeria. It also contains a much larger urban market, and proximity to that market both creates stronger commercial incentives to preserve produce quality and improves access to market information and inputs (Lee, Liu, & Chang, 2020; Ogunniyi et al., 2021). That the widest gaps occur in harvesting and storage, the two components

most closely tied to tools, structures and market-driven quality requirements, is consistent with this interpretation.

The finding carries a clear implication for the design of interventions. Although compliance is inadequate in both states, since even the higher-performing state reaches only 53.85%, the aggregate figure for the zone conceals a material disparity. Jigawa requires more intensive and specifically targeted support if the gap is to be closed, and the state-level differences illustrate more generally why sub-national variation should be taken into account in the design of agricultural development programmes, since zonal or national averages may mask disparities that determine where interventions are most needed.

Conclusion and Recommendation

Sweet potato farmers in Kano and Jigawa states possess a moderate but uneven level of knowledge of post-harvest handling. Their knowledge is well established for the harvesting and curing practices, whose consequences are immediate and visible and are therefore learned through experience, and it is weak and widely dispersed for the technically demanding transportation and storage practices, particularly refrigerated transport, the effect of road quality on deterioration and physiological weight loss in ambient storage. Compliance with the recommended Standard Operating Procedures is low to moderate, with a weighted index of 50.22% and only 52.9% of farmers meeting the compliance threshold; adherence is highest for harvesting (57.58%) and markedly lowest for transportation (31.44%), which constitutes the weakest node in the post-harvest chain. Compliance falls consistently below knowledge in the harvesting and curing components, confirming a knowledge-behaviour gap in which awareness alone does not produce practice. The resulting losses are substantial, averaging 37.50% of output and approximately NGN 213,721 per farmer, and they are concentrated at the high-volume harvesting and storage stages. Compliance is significantly and consistently higher in Kano (53.85%) than in Jigawa (46.45%), with a medium effect size, and the advantage holds across all four handling components. The post-harvest system in the study area is therefore operating at roughly half of its potential, and the shortfall is systemic rather than confined to a disadvantaged minority of farmers.

On the basis of these findings, the following recommendations are made. First, agricultural extension services should be reoriented towards post-harvest handling and should target the specific knowledge gaps identified rather than reiterating principles that farmers already hold. Extension content should concentrate on the transportation and storage components, covering loading and stacking practices, aeration, the use of protective coverings and cushioning materials, and the physiological basis of weight loss and deterioration in storage. Given that only about one in ten respondents had secondary or higher education, and that the mean was 4.68 years of formal schooling, delivery should be through practical demonstration in Hausa rather than through written material.

Second, transportation should be treated as a priority intervention area in its own right, since it is the point at which gains made earlier in the chain are lost. Practical and affordable measures are available to farmers even under existing resource constraints, including the use of tarpaulins or sacking to shield produce from direct sun, straw or similar cushioning to reduce impact damage, avoidance of overloading, and scheduling of movement outside peak heat hours. These require modest outlay relative to the value of produce currently lost.

Third, because the largest absolute losses occur at harvesting and storage, interventions must address these stages alongside transportation. Support for appropriate harvesting tools such as garden forks and spades designed for root crops, for simple shaded and ventilated curing structures, and for improved low-cost storage

structures such as pit and clamp stores would address the stages where the physical volume of loss is greatest. Fourth, given the significant and consistent gap between the two states, more intensive and state-specific support should be directed to Jigawa. Farmer exchange visits and structured peer learning programmes, in which farmers from Jigawa observe practice in higher-performing communities in Kano, offer a low-cost mechanism for transferring practice, since farmers frequently place greater trust in the demonstrated experience of other farmers than in externally generated technical recommendations. Investment in the rural road network and in market access infrastructure in Jigawa would address the structural conditions that plausibly underlie the disparity.

Finally, post-harvest loss reduction should be integrated explicitly into state and national food security strategies with measurable targets, since reducing losses offers a route to increasing food availability that requires no additional land, water or production inputs. Raising the compliance index from its present level of about 50% towards 75% would represent a substantial gain in food availability, farm incomes and the overall efficiency of the sweet potato value chain in the region.

The study is subject to two principal limitations that also indicate directions for further work. The cross-sectional design captures a single point in time and cannot trace the temporal progression of practice adoption, and the reliance on self-reported knowledge, compliance and loss data raises the possibility of social desirability and recall bias, which would tend to bias compliance upward and imply that actual compliance may be somewhat lower than the 50.22% recorded. Longitudinal work incorporating direct observation or physical measurement of losses, and extension of the analysis to the remaining states of the North-West zone, would strengthen and generalise the findings reported here.

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