

Determinants of Cold-Storage Access and Post-Harvest Technology Use Among Small-Scale Fish Vendors in Lagos State, Nigeria

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Article History	Abstract
Original Research Article	<i>Cold-storage infrastructure is critical for reducing post-harvest deterioration in fish value chains, yet access among small-scale vendors is often constrained by energy, enterprise and product characteristics. This study identified factors associated with cold-storage access and post-harvest cold-technology use among small-scale fish vendors in Lagos State, Nigeria. Respondent-level data from a cross-sectional survey of 63 vendors were reanalyzed to address a distinct secondary research question. Cold-storage access was defined as access to at least one refrigerator, freezer, or cold room. Post-harvest cold-technology use was defined as reported use of icing, chilled/refrigerated storage, freezing, or cold-room storage for at least one fish species. Exact bivariate tests and Firth bias-reduced logistic regression were used because several predictor-outcome combinations exhibited complete or quasi-complete separation. Seventeen vendors (27.0%) had cold-storage access and 23 (36.5%) used at least one cold-chain technology. Cold-storage access occurred among 70.8% of tilapia sellers but none of the non-tilapia sellers, and among 73.9% of vendors with regular or alternative power access but none without power access (both exact $p < 0.001$). Vendors with more than 10 years of fish-marketing experience also had higher unadjusted cold-storage access (44.4% vs. 13.9%; $p = 0.010$). In the bias-reduced multivariable model, tilapia marketing (adjusted OR=148.14; 95% CI: 4.79–4578.85; $p = 0.004$) and power access (adjusted OR=179.49; 95% CI: 6.99–4607.62; $p = 0.002$) were independently associated with cold-storage access, although the confidence intervals were wide due to sparse cells. For cold-technology use, tilapia marketing remained the dominant adjusted correlate (adjusted OR = 96.91; 95% CI: 10.32–910.16; $p < 0.001$). The findings indicate that post-harvest technology access in Lagos fish markets is shaped strongly by species/product requirements and enabling energy infrastructure. Policies that expand affordable power and shared cold-storage services should therefore be aligned with the storage needs of specific fish products and vendor segments.</i> Keywords: cold storage, fish marketing, post-harvest technology, small-scale vendors, Lagos State, Firth logistic regression.
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1. Introduction

Fish is highly perishable, and the time between harvest and sale can expose products to microbial, enzymatic and oxidative deterioration when temperature control is inadequate. Cold-chain technologies such as icing, refrigeration, freezing and cold-room storage can reduce the rate of quality loss, but their use depends on much more than technical knowledge alone. Infrastructure, electricity, capital, scale of operation, species handled and the form in

which fish is marketed can all shape whether a vendor is able or willing to use cold-storage technologies [1–4].

In Nigeria, aquatic-food value chains are changing rapidly, with growing aquaculture production, expanding urban demand and increasing commercialization. However, cold-chain infrastructure and reliable energy remain unevenly distributed, particularly among small-scale actors [3,5]. Studies of Nigerian fish enterprises also show that operating costs, financial constraints, business-decision

factors and processing or value-addition constraints can affect investment decisions and enterprise performance [6–8,10–12].

These conditions are particularly relevant in Lagos State. Catfish is often sold live, reducing the immediate need for conventional refrigeration before sale, whereas tilapia is more commonly sold fresh, iced or frozen. Thus, technology use is likely to reflect both enterprise capacity and product-specific storage requirements. A vendor selling live catfish may rationally rely on live holding systems, while a vendor handling frozen or fresh tilapia may require electricity-dependent cold storage.

Previous analysis of the same survey project focused on storage behaviour, perceived fish quality and cold-chain constraints. The present study addresses a different research question by treating cold-storage access and technology use as the outcomes and examining their socioeconomic, enterprise and infrastructure correlates. This secondary analysis is intended to identify which vendor and market characteristics are most strongly associated with access to post-harvest technologies.

1.1 Objectives

1. estimate the prevalence of cold-storage access and post-harvest cold-technology use among surveyed fish vendors;
2. examine bivariate associations between technology access/use and selected vendor, enterprise and infrastructure characteristics;
3. estimate adjusted associations using bias-reduced logistic regression; and
4. identify implications for post-harvest technology targeting and market infrastructure policy.

2. Materials And Methods

2.1 Data source and study design

The analysis used respondent-level data from a descriptive cross-sectional survey of fish vendors in selected urban and peri-urban markets in Lagos State, Nigeria. The original survey obtained 63 valid responses through a structured Google Forms questionnaire. The analytical unit was the individual fish vendor.

2.2 Outcome variables

Two binary outcome variables were constructed from the facility-access and storage-method items. Cold-storage access was coded as 1 when a respondent reported access to at least one refrigerator, freezer, or cold room, and as 0 otherwise. Post-harvest cold-technology use was coded 1 when a respondent reported using at least one of the following for catfish and/or tilapia: ice or an iced container, refrigerator/chilled storage, freezer/frozen storage, or a cold

room. Live holding tanks, smoking, drying, and ambient storage were not classified as cold-chain technologies.

2.3 Explanatory variables

Candidate explanatory variables were selected before modelling on conceptual and sample-size grounds. They included tilapia marketing (yes/no), access to regular electricity or generator/alternative power (yes/no), more than 10 years of fish-marketing experience (yes/no), fish-vendor/market association membership (yes/no), market location (urban/peri-urban), post-secondary education (yes/no) and enterprise scale (at least 30 kg handled on a normal business day versus lower/unknown volume). Income was not used in the main models because 27 of 63 respondents selected 'prefer not to say'.

2.4 Statistical analysis

Frequencies and percentages were used to describe the outcomes and explanatory variables. Fisher's exact test was used for bivariate 2×2 comparisons because several expected cell counts were small and some cells were zero. Ordinary maximum-likelihood logistic regression was inappropriate for the main models because tilapia marketing and power access resulted in complete or near-complete separation. Therefore, Firth bias-reduced logistic regression was used to obtain finite adjusted odds ratios (AORs), 95% Wald confidence intervals, and p-values. To limit overfitting in a sample of 63 respondents, the multivariable models were restricted to four pre-specified predictors: tilapia marketing, any power access, more than 10 years of experience, and association membership. Statistical significance was evaluated at $p < 0.05$. The very large odds ratios and wide confidence intervals associated with sparse cells were interpreted cautiously.

2.5 Relationship to the companion manuscript

This article uses the same underlying survey dataset as a companion manuscript already submitted by the authors. The companion manuscript focuses on cold-chain resilience, storage practices, perceived organoleptic quality and market constraints. The present article addresses distinct outcomes—facility access and post-harvest technology use—and introduces new respondent-level bivariate and multivariable analyses. The organoleptic-quality outcome and the storage-practice–quality correlation are not analysed here. This relationship should be disclosed to the journal editor at submission.

2.6 Ethical considerations

Ethical and administrative permission for the study was obtained from the relevant authorities before data collection. Permission to conduct the survey within the selected markets was also obtained from the appropriate market authorities. Participation was voluntary, and respondents were informed of the purpose of the study before completing the questionnaire. Informed consent was obtained from all participants, and confidentiality and anonymity were maintained throughout the

study. Data collected were used solely for research and academic purposes.

3. Results

3.1 Prevalence of cold-storage access and technology use

Seventeen of the 63 vendors (27.0%) had access to at least one refrigerator, freezer or cold room. Individually, 9

respondents (14.3%) reported refrigerator access, 16 (25.4%) freezer access and 11 (17.5%) cold-room access; these categories overlapped. Twenty-three respondents (36.5%) reported using at least one cold-chain technology for catfish and/or tilapia. Twenty-three respondents (36.5%) also had regular electricity and/or generator/alternative-power access.

Table 1. Selected characteristics relevant to technology access (n=63)

Characteristic	n	%
Urban market	40	63.5
Post-secondary education	16	25.4
More than 10 years' fish-marketing experience	27	42.9
Association membership	43	68.3
Regular electricity supply	19	30.2
Generator/alternative power	23	36.5
Any regular/alternative power access	23	36.5
Refrigerator access	9	14.3
Freezer access	16	25.4
Cold-room access	11	17.5
Composite cold-storage access	17	27.0
Any cold-technology use	23	36.5
Sells tilapia	24	38.1

3.2 Bivariate associations

Cold-storage access was highly concentrated among tilapia sellers and vendors with power access. 17 of 24 tilapia sellers (70.8%) had access to cold storage, compared with 0 of 39 non-tilapia sellers (Fisher's exact test, $p<0.001$). Similarly, 17 of 23 vendors with regular or alternative power access (73.9%) had cold storage, whereas none of the 40 vendors without power access did ($p<0.001$). Vendors with more than 10 years of marketing experience

also had greater access to cold storage than those with 10 years or less (44.4% vs. 13.9%; $p=0.010$).

For post-harvest technology use, 22 of 24 tilapia sellers (91.7%) used a cold technology, compared with only 1 of 39 non-tilapia sellers (2.6%; $p<0.001$). Technology use was also higher among vendors with power access (73.9% vs. 15.0%; $p<0.001$) and those with more than 10 years of experience (59.3% vs. 19.4%; $p=0.002$). Association membership showed a positive but non-significant unadjusted difference (44.2% vs. 20.0%; $p=0.092$).

Table 2. Bivariate associations with cold-storage access and cold-technology use

Predictor	Cold-storage access (%)	Exact p	Cold-tech use (%)	Exact p
Tilapia seller	70.8 vs 0.0	<0.001	91.7 vs 2.6	<0.001
Any power access	73.9 vs 0.0	<0.001	73.9 vs 15.0	<0.001
>10 years' experience	44.4 vs 13.9	0.010	59.3 vs 19.4	0.002
Association member	32.6 vs 15.0	0.224	44.2 vs 20.0	0.092
Urban market	32.5 vs 17.4	0.247	40.0 vs 30.4	0.588
Post-secondary education	31.3 vs 25.5	0.747	31.3 vs 38.3	0.767
Handles ≥ 30 kg/day	39.1 vs 20.0	0.141	39.1 vs 35.0	0.790

Percentages compare the predictor-positive group with the predictor-negative group. Fisher's exact test was used.

3.3 Bias-reduced multivariable models

In the Firth logistic model for cold-storage access, tilapia marketing and power access remained independently associated with access after adjustment for experience and association membership. Tilapia sellers had an estimated

adjusted odds ratio of 148.14 (95% CI 4.79–4578.85; $p=0.004$), while vendors with regular or alternative power access had an adjusted odds ratio of 179.49 (95% CI 6.99–4607.62; $p=0.002$). The very wide confidence intervals reflect sparse cells and complete separation in the

unadjusted data; the direction and significance are more informative than the magnitude of the point estimates.

In the model for post-harvest cold-technology use, tilapia marketing remained the dominant independent correlate

(AOR=96.91; 95% CI 10.32–910.16; $p<0.001$). After adjustment, the estimates for power access, experience and association membership remained positive or near-null but were imprecise and did not reach the 5% significance threshold.

Table 3. Firth bias-reduced logistic regression models

Outcome	Predictor	AOR	95% CI	p-value
Cold-storage access	Tilapia seller	148.14	4.79–4578.85	0.004
Cold-storage access	Any power access	179.49	6.99–4607.62	0.002
Cold-storage access	>10 years' experience	1.07	0.04–30.94	0.969
Cold-storage access	Association member	1.33	0.04–45.22	0.874
Cold-technology use	Tilapia seller	96.91	10.32–910.16	<0.001
Cold-technology use	Any power access	5.33	0.69–41.23	0.109
Cold-technology use	>10 years' experience	0.89	0.09–8.45	0.920
Cold-technology use	Association member	3.81	0.36–40.59	0.267

AOR = adjusted odds ratio. Confidence intervals are Wald intervals from the Firth bias-reduced fit.

4. Discussion

The secondary analysis reveals a highly structured pattern of access to post-harvest technology. Cold-storage facilities were not evenly distributed across fish vendors; access was strongly concentrated among vendors handling tilapia and among those with electricity or alternative power. This is technically plausible because frozen and chilled tilapia requires continuous or repeated temperature control, whereas the dominant catfish marketing strategy in the survey was live holding. Technology adoption in this setting should therefore be interpreted as a product-specific response rather than as a simple indicator of modernization.

The power result is equally important. No vendor without regular electricity or generator/alternative-power access reported refrigerator, freezer or cold-room access. This suggests that energy availability is not merely a background constraint but an enabling condition for cold-storage investment and use. Evidence from Nigerian aquatic food enterprises has similarly shown that electricity unreliability creates operating cost trade-offs and can constrain production and storage decisions [7].

Longer marketing experience was strongly associated with both cold-storage access and technology use in the unadjusted analysis, but its adjusted association weakened once fish species and power access were considered. This indicates that the apparent experience advantage may reflect accumulated access to particular products, infrastructure or enterprise networks rather than experience itself. Earlier Nigerian aquaculture studies have likewise shown that business decisions, value-addition investment, and enterprise performance are shaped by interacting socioeconomic and operational factors [10,11]. Association membership showed a similar pattern: members had higher

descriptive technology use, but the adjusted estimate was imprecise.

The dominance of tilapia in the models should not be interpreted to mean that cold storage is unnecessary for catfish. Rather, most catfish in the source survey were sold live, creating a different post-harvest technology pathway based on live-holding infrastructure. The result reinforces the need to distinguish product form when evaluating technology access. Policies that treat all fish vendors as having identical cold-chain requirements may misallocate resources.

The large, adjusted odds ratios and wide confidence intervals are an important limitation, not a reason to ignore the findings. They arise because the sample is small and because power access and tilapia marketing almost perfectly separate vendors with and without cold storage. Firth regression reduces the small-sample and separation bias but cannot create information that is absent from sparse cells. Future studies should therefore use larger samples across more markets and collect detailed data on ownership versus shared access, storage capacity, equipment age, energy cost, and utilization intensity.

From a practical perspective, the findings support shared, market-level infrastructure. Because individual ownership may be unaffordable for small-scale vendors, cooperatively managed cold rooms, reliable ice supply, and lower-cost energy could expand access without requiring each trader to make a large capital investment. Vendor associations may be particularly useful for collective procurement, maintenance, and scheduling of shared equipment [6]. This interpretation is also consistent with Nigerian evidence indicating that processing constraints and barriers to value-addition investment can limit technology uptake in commercial aquaculture [11,12].

5. Conclusion

Cold-storage access was limited among the surveyed fish vendors, with only 27.0% reporting access to a refrigerator, freezer, or cold room. Use of post-harvest cold technology was reported by 36.5%. The analysis shows that access is highly product- and infrastructure-dependent: tilapia marketing and regular or alternative power access were the strongest independent correlates of cold-storage access, while tilapia marketing dominated the model for technology use. Experience and association membership were descriptively associated with higher technology use, but their adjusted effects were uncertain. Interventions should therefore combine affordable energy with shared cold-storage services and be designed around the storage requirements of different fish products, rather than applying a uniform technology strategy across all vendors.

6. Recommendations

1. Develop shared cold rooms, freezers and ice-distribution facilities in fish markets, with transparent access arrangements for small-scale vendors.
2. Prioritize affordable and reliable power solutions for markets because cold-storage access was absent among respondents without regular or alternative power.
3. Design post-harvest interventions by species and product form, distinguishing live-fish holding systems from chilled and frozen product chains.
4. Use fish-vendor associations as potential platforms for collective equipment procurement, maintenance, energy purchasing and technical training.
5. Future surveys should measure equipment ownership, shared access, storage capacity, energy expenditure and actual utilization intensity, and should recruit larger samples to permit more stable multivariable estimates.

7. Limitations

The study is based on a cross-sectional sample of 63 vendors and cannot establish causality. Technology access and use were self-reported. The constructed cold-storage variable captures access to equipment but does not distinguish ownership from shared access, equipment capacity, functionality or frequency of use. Several predictor-outcome combinations contained zero cells, producing separation and very wide confidence intervals even after bias reduction. Income could not be used reliably because a large proportion of respondents declined to report it. The findings are therefore interpreted as exploratory evidence of determinants/correlates rather than precise population effect sizes.

Declarations

Conflict of interest: The authors declare no conflicts of interest or competing interests relevant to this study.

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Data availability: The anonymised data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable confidentiality and institutional requirements.

Author contributions: Awoyemi Bukunmi Damola: Conceptualization, data collection, investigation, data curation, formal analysis, literature review, and preparation of the original manuscript draft. Samuel Awolunate: Conceptualization, methodology, supervision, validation, interpretation of results, manuscript review and editing, and overall research guidance. Both authors reviewed and approved the final version of the manuscript and agree to be accountable for the integrity of the work.

Ethical approval and consent to participate: Ethical and administrative approval for the study was obtained from the relevant authorities prior to data collection. Permission to conduct the survey within the selected markets was also obtained from the appropriate market authorities. Participation was voluntary, respondents were informed of the purpose of the study, and informed consent was obtained from all participants. Confidentiality and anonymity were maintained throughout the study.

Duplicate-publication disclosure: The same survey dataset has been used in a separate companion manuscript with a different research question and outcome structure. The relationship between the manuscripts should be disclosed to the editor, and the submitted companion manuscript should be supplied if requested.

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