HEALTH PRODUCTS STORAGE: COLD CHAIN AND DRY STORAGE ASSESSMENT IN NORTHWESTERN NIGERIA

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Abstract. The study assesses the capacity and efficiency of health facilities in Katsina State, Northwestern Nigeria, to store health products that require both cold chain and dry storage. This survey-based research was conducted across randomly selected health service delivery points in all 34 Local Government Areas (LGAs) in Katsina State. Eleven data collectors, trained on the adapted USAID|DELIVER Project's Logistics Indicators Assessment Tool (LIAT), evaluated storage conditions at 314 health facilities. Six cold chain and seventeen dry storage indicators were assessed. Findings reveal better infrastructure for dry storage than cold storage. While 72-91% of facilities met most dry storage indicators, only 39% had accessible fire safety equipment. For cold storage, just 23% of facilities had electricity during the visit, 36% had functional refrigerators, and 13% maintained liquefied petroleum gas supplies for backup. Health facilities in Katsina State face challenges, particularly in cold chain storage. Investments in reliable power sources and fire safety are recommended to improve storage conditions and safeguard public health.
Keywords: *cold chain, storage conditions, health products, public health, Africa*

Introduction

Optimal storage conditions are of utmost importance when it comes to maintaining the efficacy, potency, and safety of health products throughout their entire shelf life (Fadiji et al., 2023; Ahmed et al., 2022). It is widely acknowledged that the loss of potency in drugs can have significant ramifications. However, it is vital to recognize the potential harm that can arise from degradation products as well, which can lead to adverse events and even carcinogenic effects (Glorieux et al., 2024; Yang and Kar, 2023; Hackman et al., 2020). Unfortunately, this aspect is often overlooked. In regions such as Northern Nigeria, the need for proper storage practices becomes even more critical due to a combination of factors. Not only are the populations large, but the healthcare infrastructure can also be limited (Abubakar et al., 2022a; Ezeudu et al., 2022; Aghaji et al., 2021). Katsina State, in particular, stands as one of Nigeria's most densely populated regions. With its 34 Local Government Areas (LGAs), there is a clear and urgent need for efficient storage systems to effectively meet the healthcare demands of the state (Ammani and Barau, 2023; Chukwuemeka et al., 2023; Abubakar et al., 2022b). Ensuring that health facilities across Katsina State have access to such storage systems is paramount in upholding the well-being and health of its residents. Several factors impact the storage of health products, including but not limited to the structural integrity of the facility, the availability of proper storage equipment, and the implementation of necessary environmental controls (Mishra et al., 2022). In Nigeria, particularly, cold storage faces a set of unique challenges largely due to frequent power outages that hinder the maintenance of suitable temperatures for temperature-sensitive supplies such as vaccines (Eze, 2024; Ogwengo, 2020). Additionally, dry storage is also greatly influenced by prevailing environmental conditions, with high room temperatures being a common issue in various regions, including Katsina (Sabiru et al., 2024;

Balarabe et al., 2022). Therefore, it becomes imperative for healthcare facilities in Nigeria to address these challenges effectively in order to ensure the safe storage and preservation of health products. By investing in robust infrastructure, reliable power supply, and suitable storage solutions, the Nigerian healthcare system can overcome these obstacles and safeguard the availability of critical medicines and vaccines to the population, ultimately contributing to the overall improvement of public health.

Additionally, it is crucial to acknowledge the significance of enhancing the knowledge and practices of healthcare personnel in effectively managing inventory and adhering to best practices. One of these fundamental principles is the First to Expire, First Out (FEFO) principle, which plays a vital role in minimizing waste and guaranteeing the availability of essential medical supplies (Singh et al., 2022; Chisholm et al., 2021). Notably, previous studies have extensively documented alarming levels of expired drugs in Katsina, thereby highlighting significant concerns regarding the management of donated health commodities by public health programs (Inyang, 2024; Balogun and Aka, 2022). These findings reinforce the dire need for immediate action and improved strategies to address the systematic issues surrounding the management of medical inventory in this region. By implementing comprehensive protocols and enhancing the capabilities of healthcare professionals, it is plausible to minimize waste, ensure product availability, and ultimately enhance the overall efficiency of healthcare systems. Taking proactive measures to tackle the issue of expired drugs is of utmost importance. It is crucial to establish robust systems, protocols, and guidelines that enforce strict monitoring and tracking of medical inventory. Ongoing training and capacity-building programs should be conducted for healthcare professionals to ensure their competency in handling donated health commodities. By doing so, we can reduce the chances of medications expiring before reaching patients in need. Furthermore, it is essential to strengthen collaborations between public health programs and donors. Coordinated efforts can streamline the process of managing medical inventory, allowing for better utilization and distribution of resources. Improved communication channels and data-sharing mechanisms would facilitate the timely identification of expiring drugs, enabling prompt action to prevent wastage.

Additionally, investing in innovative technologies can revolutionize the way healthcare systems manage their inventory. Implementing automated systems for stock monitoring and expiration date tracking can provide real-time updates, alerting healthcare professionals to upcoming expirations and facilitating timely actions such as redistributing medications or planning for replacements. These technologies can enhance the overall efficiency and effectiveness of healthcare systems, ensuring that no donated health commodity goes to waste. The implementation of comprehensive protocols, capacity building for healthcare professionals, strengthened collaborations, and adoption of innovative technologies are all essential steps in minimizing waste, ensuring product availability, and improving the overall efficiency of healthcare systems. By tackling these systematic issues, we can significantly enhance the delivery of healthcare services and ultimately improve public health outcomes in the region. This study aims to evaluate the storage capacity of health facilities in Katsina State, focusing on both cold chain and dry storage indicators. Findings will provide insights to guide improvements in storage practices and infrastructure, ultimately supporting better healthcare outcomes.

Materials and Methods

This cross-sectional survey collected primary data on storage conditions at health facilities through on-site verification and observation. Sample size determination considered the total number of public and private health facilities in Katsina (1,718), with a 95% confidence interval and an assumed 50% "gold-standard" adherence to key performance indicators. This yielded a sample of 314 facilities proportionally distributed across the 34 LGAs. The USAID|DELIVER Project's Logistics Indicators Assessment Tool (LIAT) was adapted to create a 23-indicator framework, covering both cold chain (6 indicators) and dry storage (17 indicators). Eleven data collectors, each assigned to three LGAs, received extensive training to ensure consistency and accuracy in data collection. Microsoft Excel was used for data aggregation, and qualitative analysis was conducted on observed trends. Ethical clearance was obtained from Pôle Universitaire Euclide's Institutional Review Board (ref: 2-0-1-9), and informed consent was secured from facility representatives.

Results and Discussion

Cold chain storage indicators

Data on cold chain storage reveals substantial gaps in facilities' ability to maintain ideal storage conditions. *Table 1* summarizes the performance of health facilities against each cold chain indicator. These results indicate that less than half of the facilities meet key requirements for cold storage. Only 23% had consistent electricity access, and just 36% had operational refrigerators, which compromised the viability of temperature-sensitive products.

***Table 1**. Result for the assessment of cold chain indicators.*

S/N	Indicator	No. of facilities that achieved the indicator	Percentage pass
1	Operational electricity on the day of the visit	74	23%
2	Functioning refrigerator(s) to store products needing cold storage	113	36%
3	Cold chain commodities kept in ideal temperature between 0 and +8 degrees centigrade	126	40%
4	Refrigerators located away from any surrounding objects (approximately ½ meter)	130	41%
5	Temperature chart up-to-date (to be up-to-date, there must be an entry for the day before the visit)	120	38%
6	Supply of paraffin or LPG for cold chain and sterilization purposes	41	13%

Dry storage indicators

Dry storage performance was more promising, with most indicators achieved by a large percentage of facilities (*Table 2*). While 16 out of 17 indicators met high standards (72-91% compliance), only 39% of facilities had accessible fire safety equipment, highlighting a critical area for improvement in health facility preparedness.

***Table 2**. Result of the assessment for dry storage conditions (Indicators).*

S/N	Indicator	No. of facilities that achieved the indicator	Percentage pass
1	Products that are ready for distribution are arranged so that identification labels and expiry dates, and/or manufacturing dates are visible	281	89%
2	Products are stored and organized in a manner accessible for First-to-Expire, First Out (FEFO) counting and general management	285	90%
3	Cartons and products are in good condition, not crushed due to	283	90%

	mishandling		
4	The facility makes it a practice to separate damaged and/or expired products from usable products and removes them from inventory	279	88%
5	Products are protected from direct sunlight	286	91%
6	Cartons and products are protected from water and humidity	288	91%
7	The storage area is visually free from harmful insects and rodents	284	90%
8	The storage area is secured with a lock and key, but is accessible during regular working hours; access is limited to authorized personnel	285	90%
9	Products are stored at the appropriate temperature according to product temperature specifications	283	90%
10	The roof is maintained in good condition to avoid sunlight and water penetration	280	89%
11	The storeroom is maintained in good condition (clean, all trash removed, sturdy shelves, organized boxes)	278	88%
12	The current space and organization is sufficient for existing products and reasonable expansion (i.e., receipt of expected product deliveries for the foreseeable future)	283	90%
13	Fire safety equipment is available and accessible (any item identified as being used to promote fire safety should be considered)	124	39%
14	Products are stored separately from insecticides and chemicals	286	91%
15	Products are stacked at least 10 cm off the floor	265	84%
16	Products are stacked at least 30 cm away from the walls, and other stacks	249	79%
17	Products are stacked no more than 2.5 meters high	227	72%

The results of this study reveal a complex landscape of health storage capabilities in Katsina State, where dry storage requirements are largely met, but cold chain conditions fall significantly short. These findings align with broader challenges documented across Nigeria and Sub-Saharan Africa, where infrastructural limitations, power instability, and resource constraints impede optimal healthcare service delivery, especially in resource-limited regions. This discussion will elaborate on each major finding, compare it with related literature, and explore potential implications for healthcare policy and practice. Cold chain storage presented substantial issues, with only 23% of facilities having operational electricity on the day of the visit and just 36% equipped with functioning refrigerators. This aligns with studies from other Nigerian states, such as Ogun and Lagos, where facilities reported similar struggles in maintaining consistent power for cold storage in the absence of reliable electricity; temperature-sensitive products like vaccines face a high risk of degradation, which could render them ineffective and even harmful if administered. The limited use of backup energy sources, such as liquefied petroleum gas (LPG), further underscores the fragility of the cold chain infrastructure, as only 13% of facilities reported adequate LPG supply. Comparative studies in low-resource settings, such as rural health centers in Kenya and Uganda, also reveal similar cold chain issues, citing power instability and inadequate refrigeration facilities as barriers to effective vaccine storage. Unlike some countries where solar-powered refrigeration has gained traction as a sustainable solution, Katsina State and similar regions have yet to fully adopt these technologies. Solar-powered systems have shown promise in rural African settings, where they have improved vaccine viability by maintaining consistent temperatures without dependence on grid electricity. This suggests that the use of alternative energy sources could address a significant portion of Katsina's cold chain deficiencies, a recommendation that is reinforced by the existing literature on sustainable health interventions in similar climates.

In contrast to the cold chain, dry storage conditions met or exceeded expectations in most areas, with 72-91% of facilities achieving compliance with essential indicators. Nearly 90% of the facilities maintained products with visible identification labels and expiry dates, organized items for First-to-Expire, First-Out (FEFO) management, and protected health products from sunlight and moisture. These findings are consistent with

studies from Ethiopia and Tanzania, where dry storage facilities were similarly effective at managing non-perishable health products through systematic labeling, organization, and physical protection. However, the low availability of fire safety equipment presents a critical concern. Only 39% of facilities had accessible fire safety resources, which could expose valuable health supplies to potential fire hazards. This mirrors findings from previous studies in West Africa, where the absence of basic safety protocols often leads to significant losses of health commodities during fire outbreaks. Given that many healthcare facilities in rural Nigeria are constructed with minimal fire-resistant materials, the lack of accessible fire safety measures could exacerbate risks to both healthcare workers and patients. Implementing fire safety protocols-such as regular fire drills, availability of extinguishers, and staff training on emergency response-should be a priority, as these are cost-effective interventions that have been shown to reduce fire-related losses significantly.

The high compliance rate for dry storage and the corresponding gap in cold chain infrastructure emphasize the importance of tailored interventions in improving storage practices. Studies in India and Southeast Asia have demonstrated that simple improvements in storage infrastructure, such as fire safety installations and backup energy solutions, have a profound impact on product quality and supply chain reliability. The World Health Organization (WHO) recommended a set of standards for health facility storage, including reliable energy sources for cold chain management and stringent dry storage requirements. Adopting these standards in Katsina could improve t of life-saving medicines and vaccines, thereby reducing the high morbidity and mortality rates associated with treatable and vaccine-preventable diseases in the region. This study also underscores the role of healthcare providers' knowledge and adherence to storage protocols, such as temperature logging and FEFO management. The relatively high compliance rate in dry storage indicates a level of familiarity with best practices among facility staff, which could be attributed to previous training initiatives in Katsina State. However, the inconsistent use of temperature charts in cold storage-observed in only 38% of facilities—suggests a gap in training specific to cold chain management. Research from Ghana and Malawi indicates that regular training sessions and refresher courses in health facilities can improve compliance with complex storage protocols, particularly in environments with frequent staff turnover. Furthermore, studies suggest that integrating training on energy usage (e.g., solar energy management) and emergency procedures could enhance the sustainability of storage practices, even in the face of resource limitations. In Katsina, reinforcing training on temperature monitoring, cold chain management, and the operational use of alternative energy sources could help maintain the integrity of temperature-sensitive health products.

Addressing the storage challenges observed in this study calls for both policy and infrastructural changes. First, there is a need for targeted investments in solar-powered refrigeration units, which could provide a reliable cold chain solution without dependence on the national grid. Solar refrigeration has proven effective in settings with similar environmental and logistical challenges, such as remote clinics in Kenya and Tanzania. Second, integrating fire safety protocols within healthcare policy so that facilities are equipped with necessary protective measures significantly reduces the risk of loss from fire-related incidents. Policy should also prioritize regular training programs for health facility staff, focusing on both dry storage best practices and the specific requirements of cold chain management. Existing programs could be expanded

to include modules on alternative energy systems and emergency management, ensuring that staff are well-prepared to manage both day-to-day storage needs and unexpected challenges.

Conclusion

This study highlights critical gaps in storage conditions for health products in Katsina State, with cold chain deficiencies posing a significant threat to public health. While dry storage conditions are generally adequate, improvements in power reliability and fire safety are essential to enhance storage capabilities. Targeted investment in solar-powered refrigeration, enhanced training for facility staff, and prioritizing fire safety equipment would address many of the identified issues, supporting safer and more effective health service delivery in the region.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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