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Health and Safety in Agricultural Storage Buildings: Implications for the Design of a Grain Processing and Storage Complex in Nigeria.

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ABSTRACT

Agricultural storage facilities play a vital role in Nigeria's food security and agro-industrial growth but remain linked to occupational hazards such as grain dust exposure, poor ventilation, equipment failure, and weak safety management. This study assessed the health and safety conditions of agricultural storage buildings in southwestern Nigeria to develop evidence-based architectural design guidelines for a proposed grain processing and storage complex. Using a quantitative approach, structured questionnaires were administered to 150 workers across Premier Feeds Mill, Eagle Flour Mills, and Crown Flour Mills, alongside five case studies. Findings showed that building conditions, lighting, ventilation, emergency exits, and safety equipment were generally rated positively. However, workers reported recurring respiratory issues, skin and eye irritation, headaches, and workplace accidents. Key risk factors identified included inadequate safety equipment, insufficient safety training, and faulty machinery, while poor building structure was considered less significant. The study concludes that although the physical infrastructure of major Nigerian grain processing facilities is relatively adequate, operational and management-related safety deficiencies persist. Enhanced safety training, improved dust and ventilation control, consistent PPE provision, and regular equipment maintenance are essential for creating safer and more sustainable agricultural storage facilities.

Keywords: Health And Safety; Agricultural Storage Buildings; Grain Processing; Workers' Perception; Occupational Health; Architectural Design.

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1. INTRODUCTION

Agricultural storage buildings are critical infrastructure in any agro-industrial economy. In Nigeria where agriculture accounts for a significant share of GDP and rural livelihoods, grain storage and processing facilities serve as essential nodes in the food value chain, connecting farm production to consumer markets.

Despite their economic importance, these facilities are frequently associated with significant occupational health and safety (OHS) hazards that compromise the well-being of the workers who operate within them daily. Workers in grain storage and processing environments are exposed to a range of documented risks including grain dust inhalation leading to respiratory disease, inadequate ventilation contributing to heat stress, mechanical hazards from grain handling equipment, confined space risks, and exposure to pesticides and fumigants (Jakob *et al*., 2021; Mendoza & Vega, 2021). In developed economies, comprehensive OHS regulatory frameworks and design standards emphasising ventilation, circulation, environmental controls, and ergonomic spatial planning have significantly mitigated these risks (Thompson *et al*., 2017). Nigeria, however, lacks equivalent regulatory enforcement and data-driven architectural evaluation frameworks that could inform safer agro-industrial design.

Existing research in the Nigerian context has largely focused on post-harvest losses and technical storage parameters such as silo capacity, moisture management, and material lifespans (Ulanga *et al*., 2021; Okparavero *et al*., 2024). The architectural dimension of safety, how building form, spatial layout, material selection, ventilation design, and hazard circulation planning contribute to or mitigate occupational risk remains significantly under-explored. This represents a critical gap in both research and professional practice. This study addresses this gap through an empirical evaluation of health and safety conditions in three major grain processing and storage facilities in southwestern Nigeria, conducted as part of the design of a grain processing and storage complex for Flour Mills of Nigeria Plc. The research investigates workers' perceptions of building conditions, environmental quality, health symptom prevalence, safety provisions, and the principal contributors to OHS risks. The findings are translated into actionable architectural design guidelines.

2. LITERATURE REVIEW

2.1 Occupational Health Hazards in Grain Storage Environments

Grain storage and processing facilities generate a unique constellation of occupational hazards. Grain dust, a complex mixture of organic particles, fungal spores, endotoxins, and pesticide residues is among the most extensively documented health risks. Chronic dust inhalation is associated with occupational asthma, chronic obstructive pulmonary disease (COPD), hypersensitivity pneumonitis, and organic dust toxic syndrome (Kirkhorn & Garry, 2000; Rylander, 1986; Ijadunola *et al*., 2005). In Nigerian flour mills specifically, studies have documented impaired lung function consistent with occupational dust exposure (Ijadunola *et al*., 2005; Mohammadien *et al*., 2013).

Beyond respiratory hazards, grain storage environments present dust explosion and fire risks (Abbasi & Abbasi, 2007; Schoeff, 2006), confined space engulfment hazards in silos and bins (NIOSH, 1994; Dyer *et al*., 2022), structural collapse risks, pest infestation and associated pesticide exposures, and musculoskeletal injuries from manual handling (Babel & Rajvanshi, 2013; Oginyi *et al*., 2017). The combination of these risks within complex mechanical and spatial environments makes grain processing facilities among the most hazardous agricultural workplaces globally.

2.2 Building Design and Worker Health

The relationship between building design and occupational health in agricultural settings is increasingly recognised but insufficiently studied. Ventilation design, spatial configuration, daylighting, and material selection all mediate the intensity and duration of worker exposures to airborne hazards (Thompson *et al*., 2017; Alonso *et al*., 2018; Hursthouse, 2018). Ramasamy (2021) argues that safety must be integrated into the architectural design process of industrial facilities from the outset rather than retrofitted as a compliance measure. In Nigeria, most grain storage facilities were designed primarily for capacity and structural stability, with limited attention to environmental quality or worker safety (Adejumo & Haruna, 2013; Gbadamosi *et al*., 2021). This is compounded by weak OHS regulatory enforcement in the agricultural sector and low involvement of the architectural profession in safety-driven agro-industrial design (Issa *et al*., 2019; Igbalajobi, 2019).

2.3 Research Gaps

A consistent gap in the literature is the absence of studies that simultaneously assess occupational health outcomes and architectural design factors in Nigerian grain storage settings. While Mosher *et al*. (2012) and Dyer *et al*. (2022) examine safety management and design interventions in grain storage, these studies are largely based in developed country contexts and do not translate directly to the Nigerian agro-industrial environment. This study responds to that gap.

3. RESEARCH METHODOLOGY

3.1 Research Design

The study adopted a quantitative research design. Structured questionnaires were administered to workers at three purposively selected large-scale grain processing and storage facilities in southwestern Nigeria: Premier Feeds Mill (Ibadan), Eagle Flour Mills (Ibadan), and Crown Flour Mills (Apapa, Lagos). A total of 150 questionnaires were administered and fully completed. Sample size was determined using Cochran's (1977) formula, appropriate for populations of unknown or large size. Sampling combined purposive and convenience approaches to capture a diversity of roles and experience levels within each facility (Obilor, 2023).

3.2 Case Study Analysis

Complementing the survey, five qualitative case studies were conducted across major grain storage facilities in Ibadan and Lagos. Each case study involved site observation using a structured checklist, photographic documentation, and spatial drawings to assess building layout, material conditions, ventilation provisions, safety signage, and emergency infrastructure.

3.3 Instruments

The questionnaire comprised six sections: (A) worker socio-economic and occupational characteristics; (B) physical and environmental building conditions; (C) emergency and safety provisions; (D) safety equipment availability and use; (E) health symptom frequency (Likert scale 1–5: Never to Always); and (F) perceived contributors to health and safety risks (Likert scale 1–5: Not at all to Very much).

3.4 Data Analysis

Descriptive statistical analysis was applied with emphasis on mean scores and standard deviations as measures of central tendency for Likert-scale items. Mean values above 3.00 on a 5-point scale were interpreted as indicating moderate-to-high frequency or perceived impact, consistent with established conventions in occupational health survey research (Alavi *et al*., 2024).

4. RESULTS AND DISCUSSION

4.1 Respondent Profile

The majority of respondents (n = 150) were male, aged 21–40, employed on permanent or contract terms, with between 1 and 10 years of service in grain storage facilities. Monthly earnings for most respondents fell in the range of ₦30,000–₦100,000. Approximately 60% reported having received some form of safety training, though a significant proportion indicated this was received only once or occasionally rather than on a regular basis. These findings indicate a workforce with substantial operational experience but inconsistent access to safety education.

4.2 Physical and Environmental Building Conditions

Workers rated the overall structural condition of storage buildings highly, with the majority selecting 'Good' or 'Excellent.' Emergency exits, lighting, and ventilation were similarly rated favourably by most respondents, suggesting that the surveyed large-scale facilities meet basic infrastructural standards. However, a notable minority reported observed structural damage, faults, or areas perceived as unsafe, indicating that infrastructure quality is not uniform across all spaces within these facilities.

Table 1. Physical and Environmental Conditions of Agricultural Storage Buildings (n = 150)

Condition	Very Poor / Poor (%)	Fair (%)	Good / Excellent (%)
Overall structural condition	8.7	18.7	72.6
Lighting quality	10.0	22.0	68.0
Ventilation quality	12.7	24.0	63.3
Emergency exit visibility	9.3	21.3	69.4
Temperature control	18.7	28.0	53.3

4.3 Health Symptom Frequency

Mean-based analysis of Likert-scale health symptom data revealed moderate-to-frequent occurrences of all five assessed conditions. Respiratory symptoms (coughing/breathing difficulties) recorded the highest mean score (3.27, SD = 1.320), followed by skin irritation (mean = 3.25, SD = 1.050), headaches and dizziness (mean = 3.11, SD = 1.090), workplace accidents and injuries (mean = 3.05, SD = 1.358), and eye irritation (mean = 2.93, SD = 1.248). All means exceeded the 3.00 midpoint of the scale with the exception of eye irritation, indicating that health impacts above neutral frequency are prevalent across the sample.

Table 2. Health Symptom Frequency Among Workers in Grain Storage Facilities (n = 150)

Health Symptom	Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Always (%)	Mean	SD
Coughing / breathing issues	8.7	24.0	25.3	15.3	26.7	3.27	1.320
Skin irritation or itching	3.3	22.0	34.0	27.3	13.3	3.25	1.050
Headaches or dizziness	5.3	23.3	40.7	16.0	14.7	3.11	1.090
Eye irritation	14.0	24.7	30.7	16.0	14.7	2.93	1.248
Accidents or injuries	16.0	24.0	16.7	26.0	17.3	3.05	1.358

The high mean score for respiratory symptoms is consistent with the documented occupational health literature on grain dust exposure (Kirkhorn & Garry, 2000; Ijadunola *et al*., 2005; Ulanga *et al*., 2021). The moderate frequency of skin irritation likely reflects contact with grain residues, fumigation chemicals, or inadequate PPE usage. Headaches and dizziness may indicate environmental stressors such as inadequate ventilation, heat accumulation, or noise; factors that are intrinsically linked to architectural design parameters.

4.4 Perceived Contributors to Health and Safety Risks

Workers' perceptions of factors contributing to health and safety risks highlighted operational and management-related issues as primary concerns. Lack of safety equipment recorded the highest mean (3.83, SD = 1.374), followed by inadequate safety training (3.60, SD = 1.366), faulty machines or tools (3.59, SD = 1.275), poor ventilation or dust exposure (3.27, SD = 1.279), and poor building structure (2.83, SD = 1.440).

Table 3. Perceived Contributors to Health and Safety Risks (n = 150)

Risk Factor	Not at All (%)	A Little (%)	Somewhat (%)	Much (%)	Very Much (%)	Mean	SD
Lack of safety equipment	12.7	6.0	10.0	28.7	42.7	3.83	1.374
Lack of safety training	15.3	5.3	12.7	37.3	29.3	3.60	1.366
Faulty machines or tools	8.0	14.0	19.3	28.0	30.7	3.59	1.275
Poor ventilation / dust exposure	12.0	15.3	26.0	26.7	20.0	3.27	1.279
Poor building structure	26.7	17.3	17.3	23.3	15.3	2.83	1.440

These findings suggest that while physical infrastructure quality is comparatively adequate, the managerial and operational dimensions of safety represent the most significant vulnerabilities. This accords with Mosher *et al*. (2012), who found that management practices and employee decisions are more predictive of safety outcomes than physical facility characteristics alone. That said, the moderate mean for ventilation and dust exposure (3.27) underscores the continuing relevance of architectural and environmental design as a contributing factor.

5. DISCUSSION

The findings of this study illuminate a structural paradox common to large-scale agro-industrial facilities in sub-Saharan Africa: physical infrastructure may meet basic standards, yet operational health and safety performance remains inadequate. The case study facilities surveyed Premier Feeds Mill, Eagle Flour Mills, and Crown Flour Mills, represent the upper tier of the Nigerian grain processing sector in terms of scale and investment, yet workers in these facilities report consistent, moderate-to-frequent health symptoms consistent with occupational hazard exposure. This suggests that infrastructure investment alone is insufficient. The architecture of safe workplaces requires an integrated approach encompassing spatial planning, environmental performance, equipment selection, management systems, and worker empowerment.

The comparatively low mean for structural condition as a risk contributor (2.83) does not eliminate architectural responsibility; rather, it shifts the emphasis toward design features that directly enable or constrain the operational behaviours identified as principal risk drivers, ventilation systems that require maintenance, equipment layouts that minimise confined space entry, and spatial configurations that support effective safety training. The prevalence of respiratory symptoms in this sample is particularly significant from a design standpoint. Dust management in grain processing environments is primarily an architectural and mechanical engineering challenge: the placement and capacity of dust extraction systems, the zoning of high-dust operations from worker rest and circulation areas, the design of cleaning-accessible surfaces, and the provision of natural cross-ventilation where feasible. These interventions are design decisions that can be embedded in the architectural programme at the schematic stage rather than retrofitted post-occupancy.

6. DESIGN IMPLICATIONS AND RECOMMENDATIONS

6.1 Architectural Design Guidelines for Grain Processing Complexes

The findings of this study yield the following evidence-based architectural design guidelines for grain processing and storage complexes:

1. **Integrated dust management systems:** Provision of mechanical dust extraction at all primary grain transfer and processing points, designed to maintain airborne dust concentrations below established occupational exposure limits. High-dust zones should be spatially separated from worker rest areas and administrative spaces.
2. **Enhanced natural and mechanical ventilation:** Given Nigeria's humid tropical climate, ventilation design must balance heat management with dust and moisture control. Hybrid ventilation strategies, combining cross-ventilation principles with mechanical extraction should be integrated into the building's structural and façade design.

3. **Safe circulation and emergency egress:** Clearly marked and unobstructed emergency exits with minimum travel distances conforming to OSHA 29 CFR 1910.272 guidelines. Dedicated safe passage routes segregating pedestrian worker circulation from vehicular and grain handling equipment movement.
4. **PPE storage and management integration:** Dedicated, accessible PPE storage points at entry zones to high-risk operational areas, designed to minimise barriers to compliance and enable visual management of equipment availability.
5. **Training and welfare facilities:** Purpose-designed training rooms within the facility, accessible to shift workers, to support regular, mandatory safety training programmes. Staff welfare provisions like canteen, clinic, changing rooms should be designed to reinforce occupational health culture.
6. **Maintainability by design:** Equipment layouts and building detailing that facilitate routine inspection, maintenance, and cleaning without requiring confined space entry where avoidable. Access gantries, maintenance corridors, and inspection hatches should be standard features.

6.2 Operational Recommendations

Beyond architectural interventions, the study recommends: mandatory and regularly recurring safety training for all facility staff; comprehensive PPE provision with monitored compliance protocols; structured preventive maintenance programmes for all grain-handling machinery; enhanced dust and air quality monitoring with threshold-based response protocols; and engagement of registered architects in the design and periodic safety review of agricultural storage buildings.

7. CONCLUSION

This study has demonstrated that health and safety conditions in Nigeria's large-scale grain processing and storage facilities, while physically adequate in infrastructure, are undermined by operational gaps in safety training, equipment provision, and maintenance culture. The empirical data collected from 150 workers across three major facilities, supported by five case study analyses, reveal a consistent pattern of moderate-to-frequent health symptom exposure and clear operational risk factors.

The findings make a case for an integrated approach to agricultural storage building design that embeds occupational health considerations into the architectural brief. Physical infrastructure cannot be divorced from the management systems and spatial configurations that enable safe operation. The architectural profession, in collaboration with industrial hygienists, facility managers, and regulatory bodies, has both the opportunity and the responsibility to design environments that protect the health of the workers who sustain Nigeria's agricultural economy.

This study's findings have been incorporated into the design of a grain processing and storage complex for Flour Mills of Nigeria Plc, a proposal that models how research-driven architectural practice can advance safer and more sustainable agro-industrial infrastructure in Nigeria and comparable developing country contexts.

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