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FACILITATING CASSAVA PROCESSING THROUGH DESIGN OF FUNCTIONAL FACTORY SPACES: A CASE STUDY OF SELECTED FACTORIES IN SOUTH- SOUTH NIGERIA

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Abstract

Cassava is a major staple crop in Nigeria and plays a significant role in food security and rural industrialization. Efficient cassava processing is essential to meeting the food and industrial demands of rapidly growing populations in cassava-producing regions. However, the efficiency of cassava processing is often hindered by inadequately designed factory spaces. Small-scale and even medium-scale processors often contend with poorly designed factory spaces that impede productivity, hygiene, and worker safety. This study investigates how functional spatial design can facilitate cassava processing in selected factories within South-South Nigeria. The case study approach, including on-site observations, and interviews. Analysis of architectural layouts, was used to identify spatial design factors that influence processing efficiency, worker productivity, and hygiene. Results revealed that workflow-oriented layouts, environmental comfort, modularity, and integrated utility systems play vital roles in optimizing cassava processing. Findings emphasise that spatial design is not merely supportive but foundational to agro-industrial efficiency. Key recommendations include implementing linear spatial layouts, enhancing ventilation, zoning wet and dry areas, and adopting modular design elements. The study culminates in the development of a prototype layout adapted to local conditions. This research contributes a practical design framework for improving cassava processing infrastructure in Nigeria and can inform policy and development efforts. The study concludes that investment in spatial design directly correlates with processing efficiency, product quality, and sustainability.

Keywords: cassava processing, cassava products, design, factory space, functional spaces

INTRODUCTION

Cassava (Manihot esculenta) is a cornerstone of food production and industrial raw material in Nigeria, with the country being the world's largest producer, and South- South region being one of the major producers in Nigeria (IITA 1992). The Crop remains one of the most important staple crops in the developing world, particularly in sub-Saharan Africa, Southeast Asia, and parts of South America (FAO, 2020). However, the potential of cassava is hampered by post-harvest losses, inefficiencies, and substandard processing practices. Especially those at the cottage and SME levels—face persistent infrastructural and design challenges. Inappropriate factory layouts often lead to inefficiencies, contamination, and product loss (Oduro et al., 2018). A core contributor to these issues is the design of processing environments. This includes the physical design of processing spaces which is often overlooked. To address these issues, factory spaces must be purposefully designed to align with cassava processing workflows.

In the south-south region of Nigeria, in the study areas, findings shows that cassava processing factories continue to face issues of inadequate spaces to sort and grade tubers, no demarcation between clean and dirty operations, Odour due to poor ventilation, peels and effluent are discarded nearby without treatment, and Factories rarely have designated composting or processing spaces for by-products.

This study focuses on how the role of architecture on the spatial and functional design of cassava processing factories influences productivity, hygiene, worker safety, and the overall value chain efficiency. The goal is to offer insight into how better factory layouts and infrastructural planning can facilitate more effective cassava processing. This paper investigates how architectural and engineering design principles can be applied to develop functional cassava processing facilities. The focus lies on improving flow, ergonomics, hygiene, safety, and expandability.

LITERATURE REVIEW

A cassava processing factory is a facility specifically designed for the production, packaging and distribution of processed cassava products. Cassava also known as manioc, yucca or tapioca root is a root vegetable widely cultivated in tropical regions and serves as a staple food for millions of people worldwide (Omodara & Olufayo, 2020). Cassava processing refers to the series of activities and techniques used to convert raw cassava roots into edible or industrial products. While it is a rich source of carbohydrate, it contains cyanogenic glycosides (toxic substance), so proper processing is essential to make it safe for consumption.

The primary purpose of a cassava processing factory is to transform raw cassava roots into value added products. This involves series of manufacturing processes such as peeling, washing, grating, fermenting, pressing, drying, and milling. These processes ensure that the cassava is converted into various forms like flour, starch pellets, chips, or other derived products.

In cassava processing factories, functional spaces refer to the distinct areas within the facility that are designed and organized to support specific steps of the cassava processing workflow.

Each space has a defined role to ensure efficient, hygienic, and safe processing of cassava into various products like garri, fufu, starch, flour, or ethanol. Some of the main functional spaces commonly found in cassava processing factories are; Raw Material Reception Area, Washing and Peeling Area, Chipping, Grating, or Crushing Area, Fermentation Area, Pressing or Dewatering Area, Drying Area, Milling and Sieving Area, Packaging Area, Storage Area, and Waste Management Areas

Factory design has been shown to influence the operational efficiency and output of agro-processing industries (Aluko & Ayoade, 2017). Agro-processing involves the transformation of raw agricultural products into finished or semi-finished goods, such as turning cassava into flour or fruits into juice. The factory's layout, workflow, equipment placement, and overall design directly affect productivity, energy consumption, safety, and product quality. Some of the operations require both wet and dry zones, and need to be spatially separated to avoid contamination (Agboola & Okonkwo, 2021). Efficient spatial organization is key to facilitating a smooth transition between these stages.

A well-designed factory will reduce handling time and spoilage, increases speed of production, and lowers labour costs. It encourages better inventory management, reduces congestion, and supports scale-up of operations as demand grows. It ensures compliance with health standards, reduces contamination risk, and boosts consumer confidence, reduces fatigue and accidents, increases output, and decreases staff turnover, and also help preserves product quality and reduces post-harvest losses.

Studies by the Food and Agriculture Organization (2019) and the International Fund for Agricultural Development (2021) have emphasized the importance of infrastructure in agro-industrial productivity. Inadequate space allocation, poor ventilation, and absence of logical workflow layouts are commonly cited constraints (Ajayi et al., 2019). However, few studies address factory space design as a determinant of efficiency. Previous work on agro-processing facilities in Ghana and Kenya suggests that space layout significantly affects both workflow and hygiene (Adeyemi, Mensah, & Oluwaseun, 2018).

In many rural and semi-urban areas of South- South Nigeria, cassava processing facilities often evolve informally, with little consideration for workflow optimization, hygiene zoning, or mechanization compatibility. The consequences include: Cross-contamination of food products, wastage due to inefficient processing lines, increased labour fatigue and risk of injury, inconsistent product quality. Addressing these issues requires not only technological interventions but also architectural and engineering solutions rooted in an understanding of local practices and constraints.

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RESEARCH METHODOLOGY

Research Design

This study employed a survey design approach using case studies of three cassava processing Centre that were purposively selected in south-south Nigeria. Focusing on the spatial and functionality of these selected factories. Structured interviews were conducted with factory managers and operators. Site visits were undertaken to map spatial layouts, workflow patterns, and equipment positioning, architectural blueprint and utility layouts were reviewed, assessment of environmental conditions, sanitation, and infrastructure were made. This approach offers an insight on how design of functional factory spaces and layout can facilitate more effective cassava processing.

Study Area

The study centred on three cassava processing factories within south- south Nigeria: The Rivers state cassava processing company, Afam/Ban-Ogoi Rivers state; The Uromi Cassava factory, Uromi Edo state; and Cassava processing factory, Ogbobagbene, Delta state; Figures 1, 2 and 3 show the location maps of the selected factories. The factories were selected to represent a range of operational scales—from smallholder cooperatives to mid-sized agro-industrial plants.

Figure 1: Rivers state cassava processing company, Afam/Ban-ogoi link road, and location map
Source: Google Map (2024)

Figure 2: Uromi Cassava Factory, location map
Source: Google Map (2024)

Figure 3: Uromi Cassava processing Factory Ogbobagbene, location map
Source: Google Map (2024)

Methods of Data Collection

Data in this research was obtained through a case study approach from primary and secondary Sources. Secondary data was obtained from existing books published and unpublished related Materials. Maps of the place, no of staff, when the factories were opened and output were got for the secondary data. It plays a key role in providing contextual, comparative, and historical information. And the primary source was obtained by Field studies through interviews and direct site observations in April 2024. The collection of data was to explore the current design conditions of selected cassava processing factories in South- southern region of Nigeria, with a particular focus on identifying recurring design challenges and best practices.

1. Case studies

Each factory was studied carefully; observations and interviews were conducted with facility personnel. The case study method helped to provide a real-world foundation for making informed decisions to improve efficiency in in cassava processing through architectural design.

2. Interviews

Structured in interviews were conducted with each participant. These interviews explored perception of spatial organization and workflow as well as sanitation and zoning. They also examined ventilation and lighting, waste management infrastructure, equipment placement, and ergonomics. Interviews were conducted in quiet areas within the factory, each lasting between 20 and 45 minutes, depending on participant's willingness.

3. Observation method

The researcher conducted systematic field observations during multiple visits to each facility. Observations focused on spatial layout, linear workflow layout, functional zoning, natural ventilation and lighting and waste management systems. An observation checklist was used to ensure consistency. Where permitted, photographs were taken to document spatial characteristics.

DISCUSSIONS

Data was collected through case studies, interviews, and structured site observations conducted across three Cassava processing factories in South-south Nigeria: The Rivers state cassava processing company, Afam/Ban-Ogoi Rivers state: The Uromi Cassava factory, Uromi, Edo state: and Cassava processing factory, Ogbobagbene, Delta state: The aim is to understand the existing state of the design of cassava processing factories, its impact on the processing of cassava into various products and the spatial experiences of both staff and customers. Thematic analysis was used to code responses and field notes, while observational data helped contextualize and verify interview findings. Thematic analysis is a widely used qualitative research method in journal publication. It involves identifying, analysing and reporting patterns or themes within qualitative data (such as interview)

Case study overview

The selected factories varied in size and production capacity but shared common challenges, notably

(i) Poor ventilation and lighting
(ii) Inefficient spatial arrangement leading to bottlenecks
(iii) Limited access to clean water and waste disposal facilities
(iv) Inadequate hygiene separation between wet and dry processing areas

1. Case Study One

*Name***:** The Rivers State Cassava Processing Company**.**

*Location***:** Afam/Ban-ogoi link road, Oyigbo local government, Rivers state.

Factory Overview: The Rivers state cassava processing company was established on 27th may 2021 (Plates 1, 2, and 3 show pictorial views of the factory). It is for the production of cassava flour. The factory is equipped with modern machines and equipment. The factory is fed with output from about 3000 farmers within the communities and farmers far and wide from neighbouring communities. With production capacity of 450 metric tons of Cassava tuber, the company also cultivates thousands of hectares of cassava for uninterrupted supply of raw materials. The machinery and equipment are configured to producer 50 kilogram bags to key into the inclusion policy of federal government thereby promoting the adoption and use of 10% high quality cassava flour (HQCF) in bread and confectionary business.

Production capacity: it has a production capacity of 450 metric tons of cassava tubers.

Products: The factory Specializes in the production of cassava flour

Size of company: 15,000 Square metres

Employment capacity; 100 persons direct employment and above 350 indirect employment

Machines/ equipment at the factory: These include

1. Dry sieve –to remove impurities
2. Paddle washer- for further washing to remove mud.
3. Cutting machine –to cut to smaller pieces.
4. Rasper – to crush to fine mash.
5. Desander –to remove sand
6. Filter press- to dehydrate
7. Flash dryer- for drying
8. Vibrating sieve – to separate course flour.
9. Packaging machine – for packaging.
10. Waste recycling plant – for waste conversion

Plate 1: Showing an aerial view of the factory
Source: Fieldwork, 2025

Plate 2: Showing machines in the factory
Source: Fieldwork, 2025

Plate 3: Showing a conveyor belt at work in the factory
Source: Fieldwork, 2025

Merits: These include

1. Efficient production layout
2. Good hygiene and quality control
3. Sound structural system
4. Efficient waste management system

Demerits: These include

1. High initial capital investment
2. Poor natural lighting considerations.

Deductions: These include

1. Functional zoning into wet and dry arrears, with intermediate holding and processing buffers should be introduced
2. Functional spaces should be introduced to allow for safe movement of workers and machinery with separate paths for raw and finished products.

Limitations encountered

Restrictions were placed on some areas as a result of critical processing activities on-going.

2. Case Study Two

Name: The Uromi Cassava Factory, Uromi, Edo State, Nigeria

Location: It is located along the Uromi-Agbor road, Edo state.

Factory Overview: The Uromi Cassava factory conceived in 2002 by former governor Chief Lucky Igbinedion as parts of efforts to industrialise the State. The factory is an agro processing factory with a capacity of 60,000 tonnes of fresh cassava tubers per year to be processed into the following industrial products (Plates 4, 5 and 6 show some of the structures and equipment at the factory).

Production capacity: It has the capacity to produce 60,000 tonnes of fresh cassava tubers per year

Products specialization: The factory produces Cassava chips, Cassava starch, Cassava flour, Garri and Re-processed waste.

Size of factory: The entire factory complex occupies about 10,000 square meters.

Employment capacity: It employs 100 persons direct employment and above 250 indirect employment

Facilities: These include

i. factory complex (30m X 60m)
ii. finished product storage warehouse (5m X 10m)
iii. a waste processing complex (6m X 15m)
iv. an administrative block with a canteen, and clinic,
v. 2 sets of electricity generators (500kva and 300kva)
vi. 11 KV electricity supply from a 1000Kva transformer substation,
vii. Roads networks and horticultural/landscaped.
viii. Water borehole with large overhead and ground storage tanks.
ix. 1.2 Km fence
x. A gate house.

Plate 4: Showing some of the structures in the factory
Source: Fieldwork, 2025

Plate 5: Showing some of the machines at the factory
Source: Fieldwork, 2025

Plate 6: Showing some machines and interior spaces at the factory
Source: Fieldwork, 2025

Merits: These include

1. Product versatility (proper space allocation which allows multiple outputs)
2. Good road network within the factory.

Demerits: These include

1. Inefficient waste management system.
2. Poor structural considerations.
3. Poor ventilation and air circulation

Deductions: These include

1. Spaces for waste and by product processing is essential
2. More headroom inside production areas should be considered

3. Case Study three

Name: Cassava Processing Factory Ogbobagbene, Delta State

Location: Ogbogbene town, Burutu local government Area of Delta state.

Factory Overview: The factory is a small scale cassava processing factory built by the Federal Ministry of Niger Delta Affairs (Now Ministry of Regional Development) located at the outskirt of the town. It is an L shaped single structure which houses the production hall, and few offices. The factory is for the production of garri, starch and tapioca popularly known as kpokpopgarri. Plates 7 and 8 shows are pictures of the external and interior of the factory.

Production capacity: Estimated production capacity is 3 tons per day of raw cassava tubers.

Products specialization: The factory is specialized in the production Of, Garri, Starch, and Tapioca

Size of factory: The entire factory complex occupies about 5000 square meters

Employment capacity: 50 persons direct employment and above 100 indirect employment

Facilities: These include

1. Factory hall
2. Offices
3. Borehole and water tank
4. Power plant

Equipment at the factory: These include

1. Motorized grater
2. Drum dryer
3. Screw jack
4. Flash dryer

Plate 7: Showing the entrance of the factory
Source: Fieldwork, 2025

Plate 8: Showing the interior of the factory
Source: Fieldwork, 2025

Merits: These include

1. Can be managed by locals with little capital.
2. Adequate natural ventilation and lighting.

Demerits: These include

1. Inefficient space management
2. Poor choice of structural system and construction.
3. Poor waste disposal system.
4. Inadequate storage spaces and facilities

Deductions: These include

1. Space for waste and by product processing should be integrated

Observational Data Summary

A structured check list was used to document factory design elements across the three sites. Key findings are shown in Table 1.

Table 1: Structured Checklist

1.	**Spatial Organisation and Workflow:** Most of the visited factories lacked a linear workflow layout. The movement of cassava tubers from peeling to drying was often convoluted, resulting in delays and unnecessary manual handling. In contrast, factories with a clear spatial progression—raw material intake → washing/peeling → grating → pressing → drying → packaging—demonstrated higher throughput and fewer errors.
2.	**Sanitation and Zoning:** Only two of the three factories had designated zones for clean and dirty operations. The absence of functional zoning in others led to frequent contamination risks, particularly in wet processing areas. Cross-flow of workers and equipment between raw and finished product zones was common.
3.	**Ventilation and Lighting:** Natural ventilation and lighting were insufficient in two facilities. Poor air circulation exacerbated moisture accumulation, which affected drying efficiency and contributed to mould growth in stored products.
4.	**Equipment Placement and Ergonomics:** Improper equipment layout was another major challenge. In some cases, grating and pressing machines were located too close to walls or obstructed movement, causing bottlenecks and posing safety hazards.
5.	**Waste Management Infrastructure:** Only one facility had an integrated waste management system. Others disposed of effluents and peels haphazardly, leading to environmental degradation and community health issues.

Source: Fieldwork 2025

Themes from interview

After analysing transcripts from factory managers and workers, three recurring themes were identified: illustrated in Table 2.

Table 2: Recurring themes

S/n	Focus	Description
Theme 1	Inefficient spatial arrangement	Workers in all three factories described the spatial arrangement as inadequate, and equated efficiency of cassava processing not only to machines but to functional factory spaces.
Theme 2	improper Equipment Placement and Ergonomics	there is a strong desire for improve equipment placement, like height, adequate space between walls or other machines
Theme 3	Readiness for change if supported	All three expressed wiliness to adopt modularity and scalability if guided and supported with resources.

Source: fieldwork 2025

Cross- Case comparative analysis

This involves examining multiple the case studies to identify similarities and differences. Table 3 below illustrates cross-case comparative highlights.

Table 3: Cross- Case comparative highlights

FEATURES	CASE 1 (RIVERS)	CASE 2 (EDO)	CASE 3 (DELTA)
Spatial Organization and Workflow:	Good	Moderate	weak
Equipment Placement and Ergonomics	Very good	Good	good
Sanitation and Zoning	Very good	Good	Weak
Natural Ventilation and Lighting	Weak	Moderate	Very good
Waste Management Infrastructure	Good	Weak	None

Source: fieldwork 2025

FINDINGS

1. **Spatial Organisation and Workflow:** Most of the visited factories lacked a linear workflow layout. The movement of cassava tubers from peeling to drying was often convoluted, resulting in delays and unnecessary manual handling. In contrast, factories

with a clear spatial progression—raw material intake → washing/peeling → grating → pressing → drying → packaging—demonstrated higher throughput and fewer errors.

2. **Sanitation and Zoning:** Only two of the five factories had designated zones for clean and dirty operations. The absence of functional zoning in others led to frequent contamination risks, particularly in wet processing areas. Cross-flow of workers and equipment between raw and finished product zones was common.
3. **Ventilation and Lighting:** Natural ventilation and lighting were insufficient in two of the facilities. Cassava processing emits high moisture and odours. Natural cross-ventilation, ridge vents, and the strategic placement of windows reduce indoor humidity and improve worker comfort (Obayopo et al., 2020).
4. **Equipment Placement and Ergonomics:** Improper equipment layout was another major challenge. In some cases, grating and pressing machines were located too close to walls or obstructed movement, causing bottlenecks and posing safety hazards.
5. **Waste Management Infrastructure:** Only one facility had an integrated waste management system. Others disposed of effluents and peels haphazardly, leading to environmental degradation and community health issues.

The analysis shows a strong correlation between factory space design and cassava processing efficiency. Functional factory spaces enable seamless workflow, reduce contamination, and lower the physical strain on workers. The lack of basic spatial planning in most facilities underscores the need for policy and design interventions. Standard factory layout models that incorporate local materials and context-specific solutions could improve outcomes significantly. Key findings can be summarised thus

a. Workflow Efficiency Factories with linear processing layouts demonstrated higher throughput. U-shaped or circular flow designs led to overlaps and cross-contamination.
b. Environmental Comfort Proper ventilation and natural lighting were associated with higher worker productivity and reduced absenteeism. Factories with clerestory windows and ridge ventilators performed better.
c. Modularity and Scalability Modular designs allowed for easy expansion and maintenance without disrupting operations. Prefabricated units were especially beneficial for start-ups.
d. Utility Access and Waste Management Proximity to water sources and integrated wastewater management systems enhanced operational sustainability and compliance with environmental standards.
e. Hygiene and Zoning Spatial separation of wet and dry zones significantly improved product quality and reduced microbial contamination. The use of food-grade flooring and washable wall surfaces was also noted as best practices.

Proposed design frame work based on the findings

A model layout is proposed featuring:

i. Linear workflow zones
ii. Natural lighting and mechanical ventilation
iii. Modular sections for peeling, grating, fermenting, and drying
iv. Separated hygiene zones with dedicated entrances
v. Integrated water and waste management systems

RECOMMENDATIONS

These are as follows

1. *Adopt Modular Factory Designs*: Introduce scalable factory templates that allow for expansion and integration of machinery without disrupting workflow.
2. *Implement Functional Zoning*: Ensure distinct areas for raw materials, processing, and packaging to improve sanitation and reduce cross-contamination.
3. *Enhance Natural Ventilation and Drainage*: Incorporate ridge vents, open walls, and sloped floors for better air flow and water disposal.
4. *Encourage Training for Workers and Managers*: Offer workshops on ergonomic equipment use, spatial maintenance, and hygienic practices.
5. *Policy Support and Incentives*: Government and development partners should provide design guidelines and incentives for factories that implement efficient layouts.

CONCLUSION

The design of functional factory spaces plays a crucial role in optimizing cassava processing in South -South Nigeria. While technological upgrades are essential, spatial efficiency, sanitation, and ergonomic design must not be overlooked. With appropriate planning, investment, and policy support, cassava processing facilities can significantly improve their output, quality, and contribution to local economies.

In other words, functional factory design is a critical enabler of efficient cassava processing. Addressing spatial challenges can unlock productivity gains, improve worker welfare, and enhance product quality. This study provides a foundational framework for redesigning and constructing cassava processing facilities in South-South Nigeria.

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