Beneficiation economics and market constraints in Nigerian ceramic raw materials: Evidence from market actors

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Abstract

The adoption of raw material beneficiation has been widely recognized as a pathway to improving industrial productivity and material quality in resource-based manufacturing sectors. However, limited empirical evidence exists regarding its financial viability and perceived investment risks among market actors in emerging economies. This study addresses this gap by examining the economic feasibility and investment constraints associated with raw material beneficiation in Nigeria's ceramic industry. A descriptive survey design was employed, and primary data were collected through an online questionnaire administered to suppliers, producers, and retailers across six Nigerian states. Responses from 11 key industry participants were analyzed using descriptive statistics and thematic analysis to generate both quantitative and qualitative insights. The results indicate that while beneficiation is perceived to enhance raw material quality and reduce impurities, its adoption is significantly constrained by high processing costs, inadequate access to beneficiation equipment, technical knowledge gaps, and uncertain market demand within a volatile macroeconomic environment. The study concludes that unlocking the economic potential of beneficiation requires targeted financial incentives, shared processing infrastructure, and coordinated risk-sharing mechanisms through industry associations. The findings contribute to the literature on investment risk, industrial development, and sustainable resource utilization in emerging economies, while providing practical insights for policymakers and industry stakeholders.

Keywords: raw material beneficiation; investment risk; ceramic industry; market constraints; Nigeria; industrial policy

Introduction

Nigeria possesses extensive deposits of clay and related minerals capable of supporting a wide range of ceramic products, including bricks, tiles, tableware,

and refractory materials (Akinwumi, 2016; Ceramic Raw Materials Development, 2014). Despite this natural endowment, many ceramic producers continue to rely on unprocessed local clays and selected imported materials. This practice exposes producers to several operational challenges, including variability in raw material quality, higher firing losses, and vulnerability to exchange-rate fluctuations that affect the cost of imported inputs (Nigeria Ceramic Tiles Market, 2024; Starting a Ceramics Manufacturing Business, 2025; Assessment of Clay Mineral Deposits, 2025).

Scientific and engineering research on Nigerian clays and industrial by-products suggests that beneficiation processes and controlled blending of raw materials—such as the incorporation of granite waste—can significantly improve the physico-mechanical properties of ceramic materials and enhance production efficiency. These treatments have been shown to produce more durable ceramic bodies while potentially reducing production costs (Characterization of Ajebo Clay, 2025; Evaluating Properties of Cellular Ceramics, 2021; Low-Cost, High-Performance Fired Clay Bodies, 2022). Consequently, raw material beneficiation represents a promising strategy for strengthening the competitiveness and sustainability of Nigeria's ceramic industry.

However, relatively limited attention has been given to how market actors—including suppliers, processors, small-scale manufacturers, and retailers—evaluate the financial implications of adopting beneficiation practices. In particular, there is a lack of empirical evidence regarding how these actors assess the trade-offs between capital investment, operating costs, processing time, potential price premiums, and demand uncertainty within their specific market environments (Ceramic Raw Materials Development, 2014). This gap is particularly significant in Nigeria, where macroeconomic volatility, rising production costs, and infrastructural constraints often limit investment capacity and undermine long-term planning in the building materials and ceramics sectors (Nigeria Ceramic Tiles Market, 2024; How Collapse of Building Materials Industry, 2025; Effect of Exchange Rate Volatility, 2025; West Africa Ceramic Tiles Market, 2025).

Given the increasing importance of value addition in resource-based industries, understanding the financial and operational dynamics influencing beneficiation adoption is critical for strengthening Nigeria's ceramic value chain. While previous studies have focused primarily on the technical performance of ceramic materials, there remains limited empirical evidence on how industry actors evaluate the economic feasibility and investment risks associated with beneficiation practices. Addressing this gap is essential for designing policies and

financial mechanisms capable of promoting the sustainable utilization of local mineral resources.

This study therefore examines how Nigerian ceramic raw material market actors perceive, adopt, and economically evaluate beneficiation practices within the industry. Using data from the **2025 Ceramic Raw Materials Market Survey**, the study analyzes patterns of raw material sourcing and utilization, the extent and forms of beneficiation adoption, perceived benefits and operational constraints, and the types of institutional or financial support required to make beneficiation economically viable (Eweka, 2025). Consistent with the orientation of Accounting, Finance, and Forensic Studies scholarship, the study aims to bridge the gap between technical potential and real-world financial decision-making by exploring how investment incentives, risk perceptions, and policy instruments shape beneficiation adoption within Nigeria's ceramic value chain.

Specifically, the study pursues the following objectives:

1. To examine the patterns of raw material sourcing and utilization among ceramic industry actors.
2. To assess the extent to which beneficiation practices are adopted within the ceramic raw materials market.
3. To identify the perceived economic benefits and operational constraints associated with beneficiation adoption.
4. To evaluate the types of institutional, financial, and infrastructural support required to make beneficiation economically viable.

In line with these objectives, the study addresses the following research questions:

1. What are the prevailing patterns of raw material sourcing among ceramic market actors in Nigeria?
2. To what extent are beneficiation techniques adopted within the ceramic raw materials market?
3. What financial and operational factors influence the adoption of beneficiation practices?
4. What forms of policy or institutional support could enhance the financial viability of beneficiation in the ceramic industry?

This study contributes to the existing literature in several ways. First, it provides empirical evidence on the financial and investment considerations associated with raw material beneficiation within Nigeria's ceramic industry—an area that

has received limited attention in previous research. Second, the study extends the literature on resource-based industrial development by linking technical beneficiation processes with financial decision-making and investment risk assessment among market actors. Third, the findings provide practical implications for policymakers, industry stakeholders, and financial institutions by identifying key barriers to beneficiation adoption and proposing mechanisms—such as shared processing infrastructure, targeted financial incentives, and industry coordination—that could enhance value addition within Nigeria's mineral-based manufacturing sector. Overall, the study contributes to ongoing discussions on sustainable industrial development, resource efficiency, and value-chain strengthening in emerging economies.

Literature Review

Technical, Financial, and Institutional Perspectives

Existing studies demonstrate that raw material beneficiation significantly improves the suitability of clay for ceramic production through various physical and chemical treatments. Empirical investigations conducted on Nigerian clay deposits—including those from Ankpa, Ajebo, and Uzuakoli—have shown that beneficiation processes such as washing, sieving, and controlled blending enhance the plasticity, strength, and firing performance of clay materials. In addition, the incorporation of industrial by-products such as granite dust or granite powder has been found to improve the mechanical properties of ceramic bodies while reducing production costs (Granite Dust as Raw Material, 2025; Recycling of Granite Powder, 2022). These studies highlight the technical feasibility of beneficiation as a strategy for improving the quality and performance of locally sourced ceramic raw materials.

Despite these technical advantages, the adoption of beneficiation practices is often constrained by financial considerations. Investment in beneficiation equipment and processing facilities typically involves substantial upfront costs that are partially irreversible once committed. Under conditions of market uncertainty, such investments may be perceived as risky by industry participants, particularly in developing economies characterized by volatile macroeconomic environments (Putnam, 2000). In Nigeria, macroeconomic challenges—including exchange rate fluctuations, inflationary pressures, and rising production costs—have further increased the financial uncertainty faced by firms operating in the ceramic and building materials sectors (Nigeria Ceramic Tiles Market, 2024). Consequently, even when beneficiation technologies are technically feasible,

their adoption may remain limited due to concerns regarding investment recovery and market demand.

Institutional factors also play an important role in shaping the adoption of beneficiation practices. Access to shared infrastructure, cooperative processing facilities, and industry associations can reduce the financial burden associated with individual investments in beneficiation technologies. Collaborative arrangements among market actors can facilitate knowledge sharing, reduce operational costs, and promote collective access to specialized equipment and technical expertise. Such institutional support mechanisms have been identified as critical enablers of technological adoption and value addition within resource-based industries (Eweka, 2025). Therefore, understanding the interaction between technical feasibility, financial risk, and institutional support structures is essential for evaluating the prospects of beneficiation adoption within Nigeria's ceramic value chain.

Research Gap

Although a substantial body of literature exists on the technical characteristics and processing improvements of clay materials, relatively limited empirical attention has been devoted to the economic and market-based dimensions of beneficiation adoption. In particular, few studies examine how ceramic market actors—including suppliers, processors, manufacturers, and retailers—evaluate the costs, risks, and potential benefits associated with beneficiation within their specific business environments.

This gap is especially significant in emerging economies such as Nigeria, where market conditions, financial constraints, and institutional arrangements strongly influence technological adoption decisions. While previous research has established the technical viability of beneficiation processes, there remains insufficient understanding of how these processes are perceived and evaluated from a financial and investment perspective by industry stakeholders. Addressing this gap is important for developing policies and institutional frameworks capable of encouraging value addition within mineral-based manufacturing sectors.

Accordingly, this study integrates technical, financial, and institutional perspectives by examining survey evidence from ceramic raw material market actors in Nigeria. By combining descriptive statistical analysis with qualitative insights from industry participants, the study provides a more comprehensive

understanding of beneficiation adoption as an economic decision embedded within real-world market conditions.

Methodology

Research Design

This study adopts a descriptive cross-sectional survey design to examine the perceptions and practices of ceramic raw material market actors in Nigeria. The survey approach is appropriate for capturing industry participants' views regarding material sourcing, beneficiation adoption, operational challenges, and financial considerations at a specific point in time. The target population consists of actors involved in the ceramic raw materials market, including suppliers, producers, retailers, and pottery shop owners operating across major ceramic production regions in Nigeria.

Data Collection

Primary data were collected through an online questionnaire administered to ceramic raw material market participants across six Nigerian states. The questionnaire consisted of both closed-ended and open-ended questions designed to capture information on raw material usage, awareness and adoption of beneficiation practices, perceived benefits and constraints, and the types of institutional or financial support required to facilitate beneficiation adoption.

A total of 11 valid responses were obtained and used for analysis. Although the sample size is relatively small, the respondents represent diverse roles within the ceramic raw materials value chain, providing valuable exploratory insights into industry practices and perceptions (Eweka, 2025).

Data Analysis

The study employs a mixed analytical approach combining descriptive statistical techniques with qualitative thematic analysis. Descriptive statistics are used to summarize respondents' material portfolios, sourcing patterns, and the extent of beneficiation adoption. These statistics provide an overview of prevailing industry practices within the ceramic raw materials market.

In addition, thematic coding is applied to open-ended responses in order to identify recurring themes related to the perceived benefits, operational constraints,

and institutional support mechanisms associated with beneficiation practices. The integration of quantitative summaries with qualitative insights enables a more nuanced understanding of how industry actors evaluate beneficiation within their specific economic and operational contexts.

Results and Discussion

Limitations and Ethical Considerations

Several limitations should be acknowledged in interpreting the findings of this study. First, the relatively small sample size (N = 11) limits the statistical generalizability of the results. Nevertheless, the study provides valuable exploratory insights into the perceptions and decision-making processes of ceramic market actors. Second, the cross-sectional research design captures industry perspectives at a single point in time and may not fully reflect changes in market conditions or technological adoption over time. Third, the reliance on self-reported responses introduces the possibility of response bias, including social desirability bias.

The study adhered to standard research ethics protocols throughout the data collection and analysis processes. Participation in the survey was voluntary, and respondents provided informed consent prior to completing the questionnaire. Confidentiality and anonymity were maintained by ensuring that individual responses were not identifiable in the reported results. In addition, collected data were securely stored and used solely for academic research purposes.

Materials Portfolio and Sourcing Patterns

The sample includes a mix of experienced and newer participants: 27% have more than 20 years of experience, 27% have 4-10 years, while newer entrants (1-3 years and less than 1 year) together make up 36% (Figure 1).

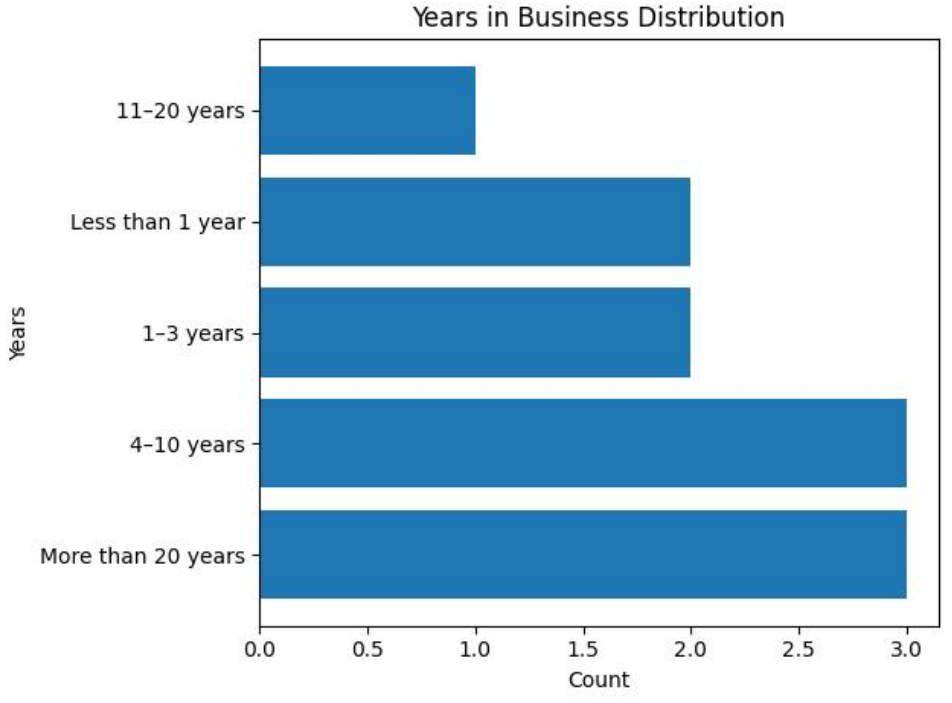

Figure 1: Distribution of Respondents by Years in Business (N=11)
Source: Primary survey data (2025).

The findings reveal that ceramic producers operate with a diversified but predominantly locally grounded raw material portfolio. The most commonly used materials include untreated local clay, kaolin, and ball clay. Specifically, untreated local clay is used by 54.5% of respondents, followed by kaolin at 45.5% and ball clay at 36.4%. In contrast, a smaller proportion of respondents reported the use of treated local clay, feldspar, granite dust, and fireclay, each representing 18.2% of responses.

This distribution indicates that the ceramic production system remains largely dependent on traditional, minimally processed raw materials. However, the presence of feldspar, granite dust, and fireclay within the material mix suggests the emergence of a subgroup of producers who are gradually engaging in material enhancement and substitution practices. This pattern reflects an early stage of technological transition in which conventional raw materials continue to dominate, while experimental adoption of performance-enhancing inputs is

gradually increasing. Such a structure provides a foundation for the future integration of beneficiation practices within the sector.

Table 1
Distribution of Ceramic Raw Materials Used by Respondents

Material	Frequency (n)
Local clay (untreated/raw)	6
Kaolin	5
Ball clay	4
Other materials	3
Local clay (treated/beneficiated)	2
Feldspar	2
Granite dust	2
Fireclay	2

Note: Multiple responses allowed (N=11).
Source: Primary survey data (2025).

The sourcing structure further reveals a strong reliance on local supply channels. Most respondents obtain raw materials directly from clay deposits, informal extraction sites, or local wholesalers. Only a small proportion depend on imported materials, primarily for specialized clays and additives. This reliance on local sourcing reflects a production environment that is highly cost-sensitive and dependent on geographical proximity to raw material deposits.

However, this structure also exposes producers to challenges associated with inconsistent raw material quality and variability in mineral composition. These challenges strengthen the argument for beneficiation as a strategic intervention capable of improving the usability and consistency of locally sourced clays. In addition, fluctuations in exchange rates and import prices continue to increase production costs for firms that rely on imported inputs, further reinforcing the economic rationale for enhancing domestic material processing capabilities (Nigeria Ceramic Tiles Market, 2024; Effect of Exchange Rate Volatility, 2025).

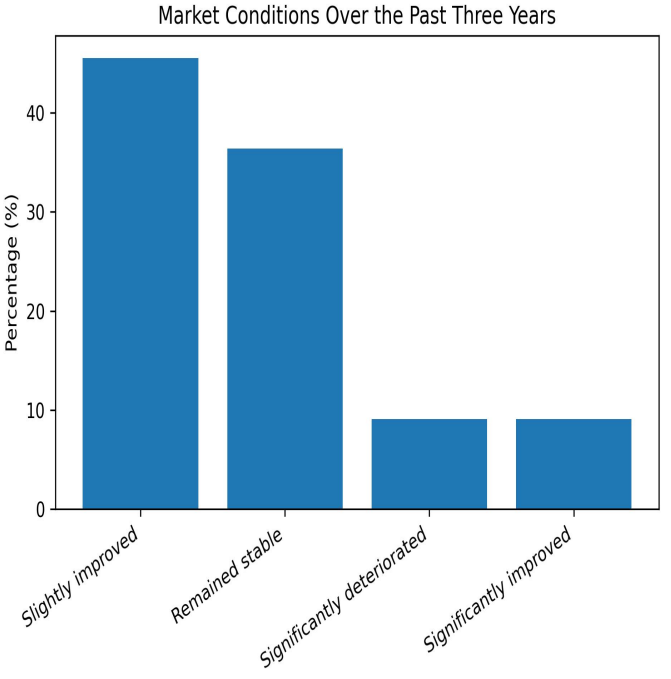

Figure 2
Perceived Market Conditions Over the Past Three Years (N = 11)
Source: Primary survey data (2025).

The perception of market conditions provides additional context for sourcing decisions. As shown in Figure 2, 45% of respondents reported that market conditions have slightly improved, while 36% indicated stability. Only 9% reported deterioration in market conditions. This distribution suggests that the ceramic materials market is experiencing modest recovery and relative stability rather than strong growth or contraction. Such a market environment typically encourages firms to prioritize operational efficiency and cost reduction strategies rather than large-scale expansion, thereby increasing the relevance of beneficiation as a cost-optimization mechanism.

Beneficiation Status and Perceived Economics

The analysis of beneficiation adoption reveals a sector that is in a transitional phase of technological diffusion. As shown in Table 2, 36.4% of respondents

currently use beneficiated raw materials, while 18.2% reported previous usage. Another 18.2% indicated that they are considering adoption, whereas 9.1% reported lack of awareness of beneficiation practices. A further 9.1% expressed no interest in adoption, and one respondent did not provide a response, representing 9.1% of the sample.

Table 2
Self-Reported Status of Beneficiation Use among Survey Respondents

Beneficiation Status	Number of Respondents
Yes, currently using	4
Yes, used in the past	2
Yes, considering it	2
No, not aware of the option	1
No, not interested	1
No response / missing	1

Note. Total number of respondents = 11.
Source: Primary survey data (2025).

When these categories are considered together, the findings indicate that 72.7% of respondents fall within the spectrum of current users, former users, or potential adopters. This suggests that beneficiation is widely recognized within the sector, although consistent and large-scale implementation remains limited. The pattern reflects a partial diffusion process in which awareness and experimentation are relatively high, but sustained adoption is constrained by structural and economic factors.

Qualitative responses provide further insight into the perceived value of beneficiation. Respondents generally associate beneficiation with improvements in product quality, greater uniformity in firing behavior, reduced levels of impurities in raw materials, and enhanced efficiency in production processes. In some cases, respondents also indicated that beneficiation reduces dependence on imported raw materials, thereby generating potential cost savings.

Despite these perceived advantages, several constraints continue to limit adoption. Respondents consistently highlighted high processing costs, inadequate access to specialized equipment, insufficient technical knowledge, and the time-intensive

nature of beneficiation processes. In addition, uncertainty regarding market acceptance and the willingness of consumers to pay premium prices for improved ceramic products further discourages investment in beneficiation. These constraints reflect broader structural challenges in Nigeria's building materials and ceramics industries, where production decisions are heavily influenced by macroeconomic instability, exchange-rate fluctuations, and weak industrial infrastructure (Nigeria Ceramic Tiles Market, 2024; How Collapse of Building Materials Industry, 2025; Effect of Exchange Rate Volatility, 2025).

Perceived Benefits and Constraints

Respondents who currently apply or have previously applied raw material beneficiation in ceramic production identified several interrelated benefits. Foremost among these is the improvement in product quality, reflected in enhanced consistency during firing and reduced variability in physical performance characteristics of ceramic wares. This finding aligns with studies that emphasize the role of beneficiation in improving the physico-chemical properties of clay bodies and enhancing overall product reliability. Additionally, respondents reported a notable reduction in impurities and surface defects in finished products, which contributes to higher aesthetic and structural quality.

From an economic perspective, respondents indicated potential cost advantages associated with beneficiation, particularly through increased utilization of locally sourced raw materials and reduced dependence on imported inputs. Prior studies have similarly documented that the incorporation of processed local materials and industrial by-products can contribute to cost efficiency and improved material performance in ceramic production (Low-Cost, Highly-Performance Fired Clay Bodies, 2022; Granite Dust as Raw Material, 2025; Recycling of Granite Powder, 2022). These outcomes suggest that beneficiation, when efficiently implemented, may enhance both technical performance and resource sustainability within the ceramic value chain.

Despite these advantages, the study reveals several critical constraints that limit the broader adoption of beneficiation practices. A significant proportion of respondents (27%) identified high processing costs as a major barrier, indicating that the financial burden of additional treatment stages may offset perceived efficiency gains. Closely related to this is the issue of inadequate access to appropriate processing equipment and facilities, which further constrains operational feasibility, particularly among small and medium-scale producers.

Another important limitation is the lack of technical knowledge regarding beneficiation techniques and their economic implications. Respondents noted that insufficient expertise affects both the selection of appropriate treatment methods and the ability to evaluate cost–benefit outcomes effectively. In addition, beneficiation processes were described as time-consuming, thereby reducing production throughput and limiting responsiveness to market demand.

Market-related uncertainty also emerged as a key constraint. Respondents expressed concern about whether consumers would be willing to pay a price premium that compensates for the additional costs associated with beneficiation. This concern is intensified by competitive pressure from low-cost imported ceramic products and persistent volatility in raw material and energy prices, which continue to affect production planning and pricing strategies (Nigeria Ceramic Tiles Market, 2024; Effect of Exchange Rate Volatility, 2025).

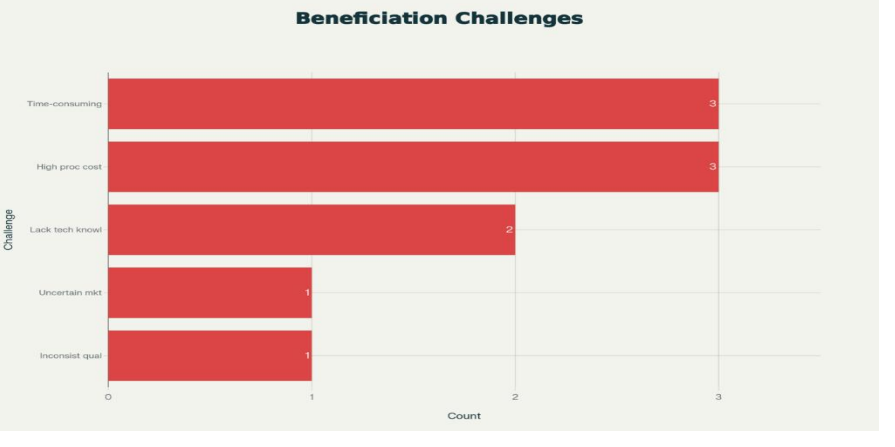

Figure 3: Challenges Faced with Beneficiation Adoption (N=11, multiple responses allowed)
Source: Primary survey data (2025).

The data presented in Figure 3 indicate that high processing cost and time-consuming processes constitute the most frequently reported barriers to beneficiation adoption, each accounting for 27% of responses. This is followed by lack of technical knowledge, which accounts for 18% of responses. Collectively, these findings highlight that both economic and capacity-related constraints play a significant role in limiting the diffusion of beneficiation practices within the ceramic production sector.

Business Challenges and Support Needs

Beyond beneficiation-specific constraints, respondents highlighted a broader set of structural and operational challenges that significantly influence their capacity to invest in process upgrading and productivity enhancement within the ceramic value chain. The most frequently reported challenge is the sourcing of quality raw materials, identified by 45% of respondents. This reflects persistent difficulties in securing consistent, reliable, and sufficiently processed inputs, which directly affects production stability and output quality.

Transportation and logistics costs (27%) also constitute a major constraint, indicating that inefficiencies in supply chain systems and inadequate transport infrastructure continue to raise production costs. Closely related to this are price fluctuations and input cost volatility (27%), which further complicate production planning and cost forecasting. Respondents similarly reported inadequate technical knowledge (27%) and equipment limitations (18%) as critical barriers, both of which restrict their ability to adopt improved production techniques, including beneficiation processes. In addition, limited access to credit and financing (18%) was identified as a significant constraint, reflecting persistent challenges in securing affordable capital for business expansion and technological upgrading.

In terms of institutional and policy support, respondents expressed clear preferences for interventions that could strengthen their operational capacity and reduce production constraints. The most frequently cited support needs include provision of equipment or equipment subsidies (36%) and improved access to credit and financing (36%), underscoring the centrality of capital investment in addressing production inefficiencies. Technical training in material quality assessment and beneficiation techniques (27%) was also identified as a key priority, highlighting the need for capacity building to enhance production competence and decision-making.

Furthermore, respondents emphasized the importance of improved market linkages and customer access (27%), suggesting that stronger value chain integration could enhance demand stability and profitability. Government support in the form of subsidies or tax incentives (18%) was also highlighted as a potential enabler of investment in process upgrading. Finally, improvements in infrastructure for transport and storage (18%) were identified as necessary to reduce logistics bottlenecks and post-production losses.

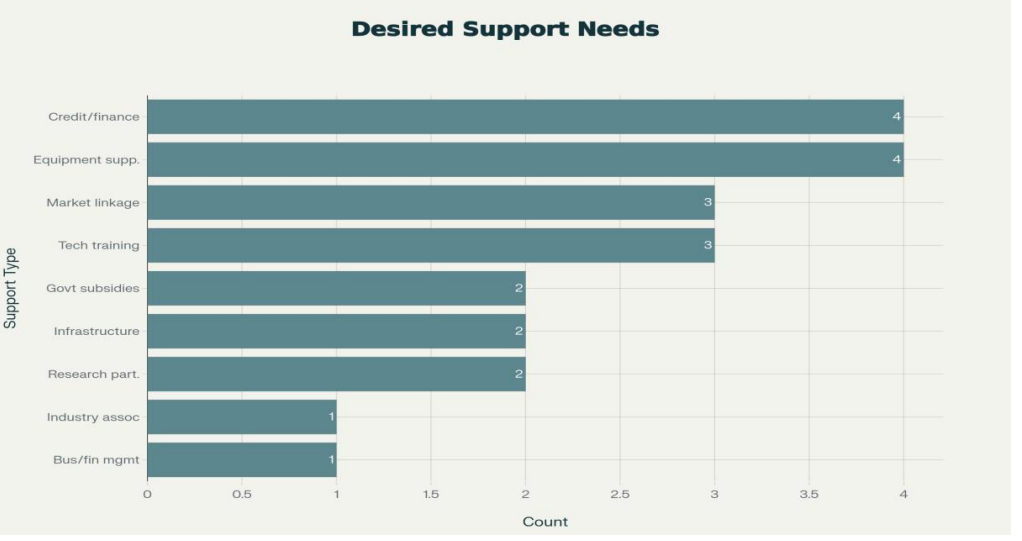

Figure 4: Desired Support to Improve Business (N=11, multiple responses allowed)
Source: Primary survey data (2025).

Discussion
The data presented in Figure 4 indicate that equipment provision and access to credit are the most critical support needs, each accounting for 36% of responses. These are followed by technical training and market linkage support, each representing 27%. The distribution of responses suggests that respondents perceive beneficiation and broader production improvement not merely as a technical issue, but as a function of interconnected systemic constraints, including financing gaps, inadequate infrastructure, limited technical capacity, and macroeconomic instability.

The survey evidence indicates that, among ceramic raw material actors in Nigeria, the decision to adopt beneficiation is shaped by a trade-off between clear technical advantages and substantial financial and market-related uncertainties. On the benefit side, both empirical responses and supporting literature consistently highlight improvements in product quality, reduced impurity levels, and enhanced firing behaviour. In addition, beneficiation facilitates the productive use of alternative and previously underutilised materials, such as granite dust, thereby expanding the resource base and potentially lowering production costs when efficiently managed (Granite Dust as Raw Material;

Recycling of Granite Powder; Low-Cost, Highly-Performance Fired Clay Bodies).

Conversely, adoption is constrained by significant cost- and capability-related barriers. These include high initial and operating costs, inadequate access to appropriate processing equipment, limited technical expertise, and the time-intensive nature of beneficiation processes, all of which collectively reduce production efficiency and scalability. These constraints are further compounded by macroeconomic instability, limited access to finance, and volatile input and output prices, conditions that are particularly burdensome for small and medium-scale operators.

From a financial economics perspective, beneficiation adoption can be conceptualised as a lumpy and partially irreversible investment undertaken under conditions of uncertainty. Rational economic agents are therefore likely to delay full-scale adoption until expected benefits sufficiently outweigh both implementation costs and the option value of waiting for better information. This helps to explain why some respondents report partial adoption, experimentation, or discontinuation after initial use, despite acknowledging the technical merits of the process. It also underscores the importance of reducing perceived investment risk through policy and institutional support mechanisms that improve predictability in both costs and market demand.

This interpretation is consistent with real options theory, which posits that firms may defer irreversible investment decisions under uncertainty until conditions become more favourable and the expected net present value exceeds the value of maintaining flexibility (Dixit & Pindyck, 1994). Within this framework, constraints such as limited access to credit and inadequate equipment reflect the absence of enabling conditions required to convert technical potential into sustained industrial uptake.

Overall, the findings suggest that the Nigerian ceramic raw materials sector is experiencing a gradual but uneven shift toward material upgrading and process innovation. While traditional raw materials remain dominant in production practices, there is clear evidence of emerging experimentation with blended and processed material inputs. The partial adoption of beneficiation indicates that the concept is both recognised and technically appreciated within the industry; however, full-scale implementation remains limited by structural and institutional constraints.

The results further demonstrate that adoption is not determined solely by awareness or technical knowledge, but by the interaction of economic feasibility, technical capacity, and market uncertainty. Consequently, beneficiation adoption should be understood as a structurally constrained innovation process rather than a purely knowledge-driven transition. The sector therefore appears to be positioned at an intermediate stage of technological maturity, characterised by incremental improvements and selective experimentation rather than widespread diffusion or full industrial transformation.

Conclusion and Recommendations

Conclusion

This study examined the financial viability, perceived risks, and adoption dynamics of raw material beneficiation within the Nigerian ceramic industry. The findings indicate that, despite clear technical advantages such as improved material quality, enhanced product performance, and the potential for cost efficiency, the adoption of beneficiation remains constrained by financial limitations, market uncertainty, and weak institutional coordination.

The evidence suggests that while market actors recognize the long-term value of beneficiation, short-term investment risks, inadequate access to finance, and limited infrastructural support significantly slow its diffusion. In addition, fragmented industry structures and weak quality assurance mechanisms further reduce incentives for large-scale adoption. Overall, the study establishes that beneficiation adoption is not purely a technical decision but a complex interaction of economic, institutional, and governance factors.

Recommendations

Based on the findings of this study, several policy and practice-oriented recommendations emerge.

First, with respect to financial and development policy, targeted subsidy and tax-incentive schemes should be introduced to support the acquisition of beneficiation equipment and the establishment of shared processing facilities. Such interventions may be more effective if channeled through existing professional and trade associations, which can also serve as coordinating platforms for cooperative beneficiation centres. In addition, improved access to

credit facilities and structured risk-sharing instruments is essential to reduce the financial burden and uncertainty associated with adoption.

Second, in the area of technical and research support, there is a need to prioritize demonstration projects that clearly illustrate the cost implications and performance advantages of beneficiation under real production conditions. This should be complemented by the development of simplified beneficiation protocols and practical training modules tailored to the capacities of small- and medium-scale operators in the ceramic value chain.

Third, regarding market organization and coordination, industry associations should be strengthened as mechanisms for collective action, particularly in the areas of bulk procurement of inputs and shared access to processing infrastructure. Furthermore, the introduction of quality labelling or certification schemes for beneficiated ceramic products would help to improve market recognition and potentially enhance consumer confidence and demand.

Finally, from a forensic accounting and governance perspective, there is a need to develop structured audit protocols to monitor the utilization of public subsidies and incentives. In addition, transparent accounting and reporting systems should be institutionalized within industry associations to enhance accountability and reduce the risk of fund mismanagement.

Future Research Directions

Future research should extend the current findings in several important directions. First, there is a need for detailed cost–benefit analyses of different beneficiation technologies and approaches across varying scales of production, in order to better inform investment decisions. Second, longitudinal studies could be conducted to track the financial performance and sustainability of cluster-based beneficiation initiatives over time.

In addition, further research should examine how ceramic market actors make investment decisions under conditions of uncertainty, particularly in relation to perceived risk, access to finance, and institutional support. Finally, future studies may explore the role of price premiums and market incentives in encouraging wider adoption of beneficiation practices within the Nigerian ceramic industry.

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