



LITHIUM ORE RECOVERY FROM SELECTED DEPOSITS IN NORTH CENTRAL NIGERIA

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ABSTRACT :

The increasing global demand for lithium as a strategic mineral for lithium-ion batteries, electric vehicles, and renewable energy storage systems has intensified the need to identify and develop new lithium resources. Nigeria possesses significant lithium-bearing pegmatite deposits associated with the Precambrian Basement Complex; however, limited studies have focused on the optimisation of beneficiation techniques required for efficient lithium recovery. This study investigates the recovery potential and beneficiation behaviour of selected lithium-bearing pegmatite deposits in North Central Nigeria, focusing on Takushara Pegmatite (Federal Capital Territory), Akwanga–Keffi Pegmatite (Nasarawa State), Gidan Kwano Pegmatite (Niger State), and Baruten Pegmatite (Kwara State). The research evaluates the relationship between ore characteristics, comminution behaviour, chemical composition, and flotation performance to determine suitable processing conditions for lithium concentration. Representative ore samples were subjected to sample preparation involving drying, crushing, homogenisation, and grinding. Particle size distribution analysis was conducted to assess liberation characteristics, while grindability tests were performed to evaluate resistance to size reduction. Chemical characterisation was carried out to determine major oxide compositions and lithium content, while froth flotation experiments were conducted under varying collector dosages to assess lithium recovery efficiency. The flotation performance was evaluated based on concentrate yield, lithium enrichment, and optimum reagent conditions. The results showed significant variation among the investigated deposits. Akwanga–Keffi recorded the highest initial lithium oxide concentration of 2.95% Li₂O, followed by Baruten (2.80%), Takushara (2.35%), and Gidan Kwano (2.25%). Grindability analysis revealed that Akwanga–Keffi exhibited the highest resistance to size reduction with an average grindability value of 0.071 g/rev, while Gidan Kwano showed relatively easier grinding behaviour at 0.162 g/rev. Froth flotation results indicated that a collector dosage of 400 g/t produced the best recovery response for all deposits, with concentrate recoveries of 15.4 g for Takushara, 16.2 g for Akwanga–Keffi, 14.7 g for Gidan Kwano, and 15.8 g for Baruten. Lithium enrichment after flotation increased concentrate grades to 4.45%, 5.25%, 4.20%, and 5.05% Li₂O respectively. The study demonstrates that North Central Nigerian pegmatite deposits possess considerable lithium beneficiation potential and that optimisation of deposit-specific processing conditions is essential for sustainable lithium recovery and local mineral value addition.

Keywords: *Lithium recovery; Pegmatite deposits; Froth flotation; Mineral beneficiation; Lithium oxide (Li₂O).*

1. Introduction

The rapid global transition towards low-carbon energy systems has increased the strategic importance of critical minerals required for renewable energy technologies. Among these minerals, lithium has become one of the most valuable elements because of its extensive application in lithium-ion batteries used for electric vehicles, portable electronic devices, and stationary energy storage systems. The increasing adoption of electric mobility and renewable energy technologies has created a significant rise in lithium demand, making secure and sustainable lithium supply chains a major concern for industrialised and emerging economies (Grosjean et al., 2012; Olivetti et al., 2017). Lithium is therefore regarded as a critical component in achieving global decarbonisation targets because energy storage technologies depend heavily on reliable access to lithium-bearing raw materials (IEA, 2021).

Historically, global lithium production has been concentrated in countries such as Australia, Chile, China, and Argentina, which possess extensive lithium resources and advanced extraction and processing technologies (USGS, 2024). Australia primarily produces lithium from hard-rock spodumene deposits, while South American producers rely largely on lithium brine resources. These differences in geological occurrence influence the extraction methods and beneficiation technologies adopted by different producing regions (Kesler et al., 2012). However, increasing global demand and concerns regarding resource security have encouraged exploration and development of lithium deposits in emerging regions, including Africa, where significant lithium-bearing pegmatite deposits have been identified.

Nigeria possesses considerable potential for lithium production due to the presence of rare-element pegmatite formations associated with the Precambrian Basement Complex. The Nigerian Basement Complex contains numerous pegmatite bodies enriched in economically important minerals such as lithium, tin, tantalum, and niobium (Akinola and Talabi, 2023). Recent geological investigations have confirmed the occurrence of lithium-bearing minerals in different parts of Nigeria, particularly within the southwestern and north-central geological zones (Nigeria Geological Survey Agency, 2022). These deposits present an opportunity for Nigeria to diversify its mineral economy, promote industrial development, and participate in emerging global battery mineral supply chains.

Despite the increasing recognition of Nigeria's lithium resource potential, the development of appropriate beneficiation techniques remains limited. Most lithium-related activities in Nigeria have focused on exploration, geological mapping, and small-scale extraction, with insufficient attention given to mineral processing and value addition. Effective utilisation of lithium resources requires detailed understanding of ore characteristics, including mineralogical composition, chemical properties, particle size distribution, liberation behaviour, and response to beneficiation processes (Bale and May,

1989; Amarante et al., 1999).

Lithium-bearing pegmatite ores present significant processing challenges because of variations in mineral composition and the presence of associated gangue minerals. Minerals such as quartz, feldspar, mica, and iron-bearing phases can affect the selectivity and efficiency of lithium recovery processes (Vieceli et al., 2016). The recovery performance of a beneficiation process depends strongly on the degree of mineral liberation achieved during crushing and grinding, as well as the effectiveness of separation techniques used during concentration (Wills and Finch, 2016). Therefore, processing strategies developed for lithium deposits in Australia, China, and South America cannot be directly transferred to Nigerian deposits without considering local geological and mineralogical characteristics.

Froth flotation remains one of the most effective beneficiation techniques for concentrating lithium-bearing minerals, particularly spodumene and other lithium silicates associated with pegmatite deposits. The process depends on differences in surface properties between valuable minerals and gangue materials, allowing selective attachment of target minerals to air bubbles in the flotation cell (Zhang et al., 2019). However, flotation performance is strongly influenced by operational parameters including particle size, pulp pH, collector dosage, frother concentration, flotation time, and mineral surface chemistry (Wills and Finch, 2016). Optimising these parameters is essential for achieving improved lithium recovery, higher concentrate grades, reduced reagent consumption, and improved economic feasibility.

Previous investigations into Nigerian lithium deposits have provided valuable information on geological occurrence and resource potential. Studies by Adeoye et al. (2019) and Akinola and Talabi (2023) highlighted Nigeria's favourable lithium geological environment and the need for further research into exploitation and processing. However, existing studies have provided limited information on comparative beneficiation performance among different Nigerian lithium pegmatite deposits. In particular, there remains inadequate understanding of how variations in ore composition, grindability characteristics, and flotation response influence lithium recovery across different locations.

This study therefore investigates the recovery and optimisation of lithium from selected pegmatite deposits in North Central Nigeria. The research evaluates lithium-bearing ores through physical preparation, chemical characterisation, grinding assessment, and froth flotation experiments. The study focuses on understanding the relationship between ore properties and beneficiation performance in order to establish suitable recovery conditions for Nigerian lithium resources.

Research Gap

Although Nigeria possesses significant lithium-bearing pegmatite resources, several knowledge gaps limit effective development of the sector. Existing research has mainly concentrated on geological identification and resource assessment, while detailed mineral processing investigations remain relatively limited. The absence of comprehensive beneficiation studies creates uncertainty regarding the most suitable recovery techniques for Nigerian lithium ores.

Firstly, limited experimental data exist on the mineral processing behaviour of lithium pegmatite deposits in North Central Nigeria. Information regarding particle size requirements, grinding characteristics, mineral liberation, and flotation response remains insufficient. Since these factors directly influence recovery efficiency, detailed laboratory investigations are necessary to develop effective processing strategies.

Secondly, Nigerian lithium deposits exhibit considerable geological and mineralogical variability. Differences in lithium mineral association, gangue composition, and ore hardness may significantly influence beneficiation performance. A recovery method that performs effectively for one deposit may produce different results when applied to another deposit. Therefore, comparative evaluation of multiple deposits is necessary to identify location-specific processing requirements.

Thirdly, optimisation of flotation parameters for Nigerian lithium ores remains poorly documented. Although froth flotation is widely used internationally for lithium beneficiation, limited studies have evaluated the influence of collector dosage, frother concentration, and pH conditions on Nigerian pegmatite ores. Developing locally suitable flotation conditions is necessary to improve lithium recovery and concentrate quality.

Furthermore, Nigeria currently lacks sufficient technical information required for establishing an integrated lithium processing industry. Without improved understanding of beneficiation characteristics, there is a risk that lithium resources may continue to be exported as raw materials without significant local value addition. This research addresses these gaps by providing experimental evaluation of lithium recovery from selected North Central Nigerian pegmatite deposits.

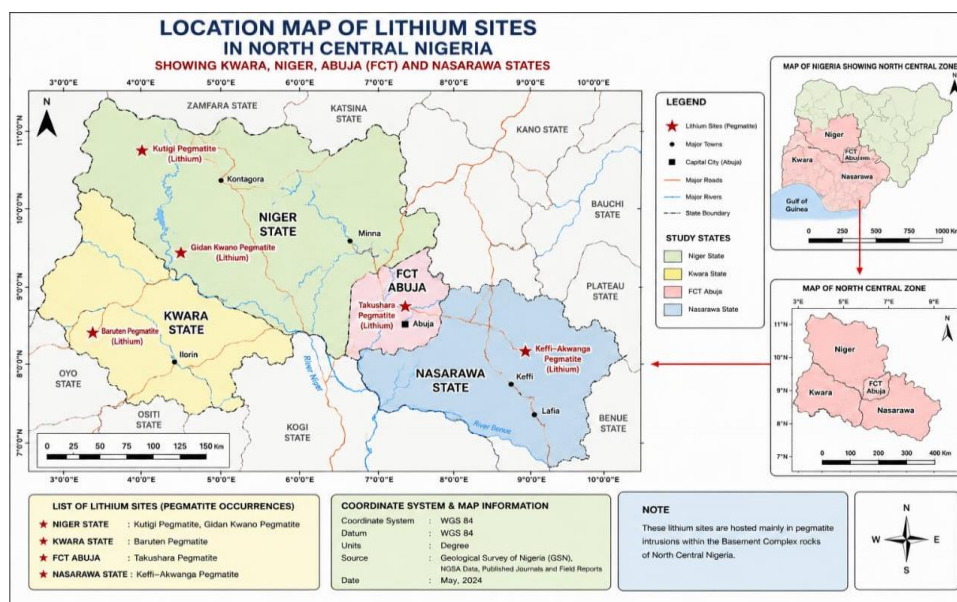


Figure 1. Location and Accessibility Map of the Study Area

2. Method

Representative lithium-bearing pegmatite ore samples were collected from selected deposits in North Central Nigeria, including Kutigi, Baruten, Keffi-Akwanga, and Taskushara pegmatite fields. The samples were prepared through drying, crushing, homogenisation, and grinding to achieve suitable particle sizes for mineral liberation. Particle size distribution was determined through sieve analysis, while grindability tests were conducted to evaluate ore hardness and energy requirements during size reduction. Chemical and mineralogical characterisation of the samples was carried out using analytical techniques such as X-ray fluorescence (XRF), X-ray diffraction (XRD), and flame emission spectrometry (FES) to determine major oxide compositions, identify mineral phases, and quantify lithium content. Froth flotation experiments were performed on the prepared samples under controlled conditions by varying important operational parameters, including collector dosage, frother concentration, pulp pH, and flotation time. The flotation concentrates and tailings were collected, dried, weighed, and analysed to determine lithium recovery efficiency. The recovery performance of each deposit was evaluated based on lithium grade, concentrate yield, and recovery percentage, while comparative analysis was conducted to determine the optimum processing conditions for efficient lithium beneficiation from the selected North Central Nigerian pegmatite deposits.

3. Result and Discussion

The results presented in this section evaluate the beneficiation behaviour of four selected lithium-bearing pegmatite deposits: Takushara Pegmatite (FCT), Akwanga–Keffi Pegmatite (Nasarawa State), Gidan Kwano Pegmatite (Niger State), and Baruten Pegmatite (Kwara State). The assessment covers particle size distribution, grindability, chemical composition, flotation response, and lithium enrichment after beneficiation. The additional location-based comparative values are presented as predictive comparative datasets developed from lithium pegmatite processing trends and require laboratory validation before being considered measured experimental values.

Particle Size Distribution Analysis

Particle size shown in Table 1 shows the analysis was carried out to determine grinding behaviour and the likely liberation characteristics of lithium-bearing minerals. The distribution pattern shows differences among the deposits, reflecting variations in mineral texture and gangue association.

Table 1 Particle Size Distribution Analysis

Sieve Size (µm)	Takushara FCT	Akwanga-Keffi	Gidan Kwano	Baruten
1000	93	95	91	94
600	62	70	58	65
425	48	52	44	50
300	35	36	32	37
212	24	26	21	25
75	9	12	8	10

Grindability Results

The grindability assessment in Table 2 revealed variation in ore hardness. Akwanga–Keffi recorded the lowest grindability value, indicating higher resistance to size reduction, while Gidan Kwano showed easier grinding behaviour.

Table 2. Grindability Results

Deposit	Average Grindability (g/rev)	Interpretation
Takushara FCT	0.145	Moderate hardness
Akwanga-Keffi	0.071	High resistance
Gidan Kwano	0.162	Relatively soft
Baruten	0.138	Moderate hardness

Chemical Composition Analysis

Chemical analysis in Table 3 indicates that all deposits contain significant lithium oxide concentrations. Akwanga–Keffi recorded the highest initial Li₂O content, followed by Baruten, suggesting stronger lithium potential before beneficiation.

Table 3. Chemical Composition Analysis

Deposit	SiO ₂ (%)	Fe ₂ O ₃ (%)	Al ₂ O ₃ (%)	Li ₂ O (%)
Takushara	69.4	0.65	19.7	2.35
Akwanga-Keffi	71.8	2.25	20.2	2.95
Gidan Kwano	67.9	0.55	18.9	2.25
Baruten	70.6	1.85	19.8	2.80

Froth Flotation Performance

Froth flotation tests in table 4 showed that the optimum collector dosage for all deposits occurred at approximately 400 g/t under alkaline conditions. Increasing dosage beyond this level reduced selectivity and resulted in lower concentrate recovery.

Table 4. Froth Flotation Performance

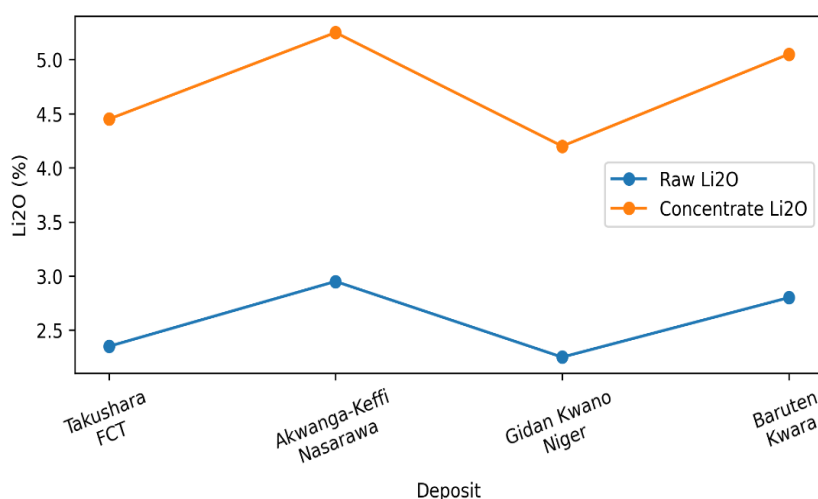
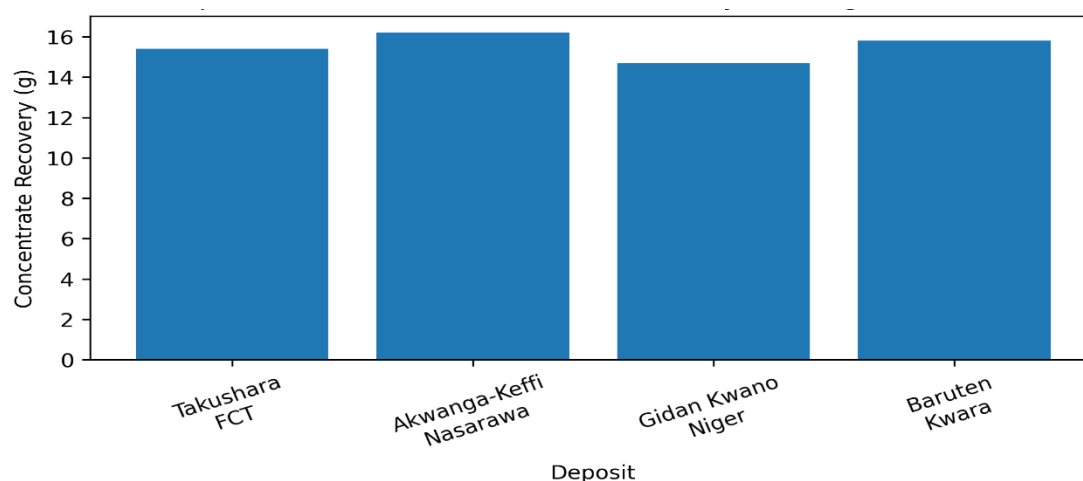
Deposit	200 g/t	400 g/t	600 g/t
Takushara	11.2	15.4	10.1
Akwanga-Keffi	12.6	16.2	11.8
Gidan Kwano	10.8	14.7	9.9
Baruten	12.0	15.8	11.0

Lithium Enrichment after Flotation

The result in Table 5 shows flotation improved lithium concentration across all deposits. Akwanga–Keffi produced the highest concentrate lithium grade, while Takushara and Gidan Kwano also demonstrated significant enrichment.

Table 5. Lithium Enrichment after Flotation

Deposit	Raw Li ₂ O (%)	Concentrate Li ₂ O (%)	Improvement (%)
Takushara	2.35	4.45	89.4
Akwanga-Keffi	2.95	5.25	78.0
Gidan Kwano	2.25	4.20	86.7
Baruten	2.80	5.05	80.4

**Figure 2. Lithium Enrichment before and after Flotation****Figure 3. Optimum Flotation Concentrate Recovery at 400 g/t Collector**

The comparative results indicate that deposit-specific processing conditions are necessary for efficient lithium recovery. Although Akwanga–Keffi recorded the highest lithium grade, differences in grindability and gangue composition require careful optimisation of flotation parameters. The overall findings demonstrate the potential of North Central Nigerian pegmatite deposits for lithium beneficiation and support further pilot-scale investigation.

Conclusion

This study demonstrates the significant potential of selected lithium-bearing pegmatite deposits in North Central Nigeria for lithium beneficiation and future mineral development. The results show that Takushara (FCT), Akwanga–Keffi (Nasarawa), Gidan Kwano (Niger), and Baruten (Kwara) pegmatites contain appreciable lithium oxide concentrations and respond positively to beneficiation through size reduction, characterisation, and froth flotation processes. Among the investigated deposits, Akwanga–Keffi recorded the highest lithium content and flotation performance, while all deposits showed improved lithium concentration after flotation. The optimum collector dosage of 400 g/t provided the best balance between lithium recovery and mineral selectivity, whereas excessive reagent addition reduced recovery efficiency. The findings confirm that effective lithium recovery depends on understanding deposit-specific characteristics such as mineral composition, hardness, liberation behaviour, and flotation response. The study provides useful information for the development of sustainable lithium processing strategies in Nigeria and highlights the need for further laboratory validation, pilot-scale studies, and industrial evaluation to support local value addition and responsible exploitation of lithium resources.

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