

Production and Characterisation of Potassium Nitrate from Wood Ash Extract and Nitric Acid

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Abstract

Wood ash, a readily available agricultural by-product rich in potassium compounds, was leached with distilled water to extract soluble potassium salts. This study focuses on the synthesis and characterisation of potassium nitrate (KNO_3) from wood ash and nitric acid. The extract obtained was reacted with dilute nitric acid (0.1 M) to form potassium nitrate. The resulting product was purified through recrystallization and drying. Characterisation of the synthesised salt was carried out using simple physical and chemical methods, including melting point, solubility tests, thermal stability, and elemental analysis to confirm the presence of potassium and nitrate ions. The results confirmed the successful formation of pure potassium nitrate with properties consistent with industrial-grade. The process demonstrates a simple, cost-effective, and eco-friendly approach to converting wood ash waste into a valuable industrial and agricultural chemical. This study highlights the potential of using renewable materials in inorganic salt production and promotes sustainable resource management.

Keywords: *Potassium nitrate, Wood ash, Nitric acid, Recrystallization, Waste utilization.*

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Background to the Study

Potassium nitrate (KNO_3), commonly known as saltpetre, is an inorganic crystalline compound that has played a significant role in human civilization for centuries. It is a naturally occurring nitrate salt that combines potassium (K^+) and nitrate (NO_3^-) ions. Historically, potassium nitrate was first recognized for its role in the manufacture of gunpowder during the medieval period, where it became a crucial component in military technology and mining operations (Moldoveanu & David, 2020). In addition to its military applications, it has long been utilized in agriculture as a source of nitrogen and potassium, two macronutrients essential for plant growth (Lide, 2005). In the modern world, KNO_3 continues to be an important industrial chemical, with applications spanning fertilizer production, food preservation, glass manufacture, ceramics, and pyrotechnics (Chaturvedi & Dave, 2013). One of the key challenges in potassium nitrate production has historically been the availability of raw materials. Early methods of saltpetre production relied on natural deposits and the leaching of soils enriched with nitrates from organic decomposition. In many cultures, particularly in Asia and Europe, heaps of organic matter, including manure, urine, and plant residues, were used to produce nitrate-rich efflorescences that could be harvested and purified (Demeyer et al., 2001). However, with the advancement of chemistry in the eighteenth and nineteenth centuries, more controlled methods of synthesis were developed. These include the neutralization of nitric acid (HNO_3) with potassium-containing compounds such as potassium carbonate (K_2CO_3), potassium hydroxide (KOH), or potassium chloride (KCl), thereby producing potassium nitrate in a more predictable and scalable manner (Misra et al., 1993).

Wood ash, the inorganic residue left after the combustion of wood biomass, represents a low-cost and renewable source of potassium. Its composition depends on the type of biomass, soil conditions, and combustion parameters, but it typically contains significant amounts of potassium in the form of potassium carbonate (K_2CO_3) and potassium oxide (K_2O), as well as calcium, magnesium, sodium, and trace elements (Yao et al., 2013). For centuries, wood ash has been used in rural communities for soap making, soil enrichment, and as a raw material in saltpetre production. The potassium salts present in wood ash are water soluble and can be extracted through leaching, which provides a suitable feedstock for the synthesis of potassium nitrate when reacted with nitric acid (Demeyer et al., 2001).

In Bangladesh, wood ash is regularly used in banana plantations in terrace areas. Farmers say wood ash prevents diseases and improves water use efficiency. Wood ash is a good source of potash and lime; it also improves the pH of acidic soils in a manner similar to agricultural lime [Alberta, 2002]. Wood ash had long been regarded as a source of potassium for plant growth (1-13% K by weight) but it also contains appreciable quantities of Ca (20-30%), P (0.3 - 0.4%), Mg (1- 3%) and smaller amounts of S, Mn, Fe, B, Cu and Zn (Etiegni et al, 1991). Emmanuel, 2014 asserted that "The wood ash extract increased the values of plantain bunch weight, weight of fingers, diameter, length and finger population more than neem leaf and this could be traced to its very high K, Ca and Mg nutrients which subsequently increased the soil organic matter, K, Ca and Mg for uptake by plantain. This finding was supported by who

reported that wood ash is a good source of potash and lime which encouraged the growth and yield of plantain. The increase in soil pH under wood ash extract compared to others was traced to its high K, Ca and Mg and could be effective as a liming material unlike the NPK 15-15-15 fertilizer which with the continuous use could decrease soil pH. The soil pH been reported to influence nutrient uptake and availability reported that oil palm bunch ash, wood ash and cocoa pod husk improved soil K, Ca and Mg nutrients and corrected soil acidity in an Alfisol grown to coffee and maize. Some studies also reported that industrial wood ash was a good soil amendment for crop production."

Characterization of synthesized KNO_3 is typically achieved using modern analytical techniques. X-ray diffraction (XRD) can confirm the crystalline phases present, Fourier-transform infrared spectroscopy (FTIR) can verify functional groups, while scanning electron microscopy (SEM) provides insight into surface morphology and particle size distribution (Moldoveanu & David, 2020). These techniques help in verifying not only the formation of potassium nitrate but also its degree of purity relative to impurities from the wood ash precursor. The synthesis of potassium nitrate from wood ash and nitric acid is therefore significant in both scientific and practical contexts. Scientifically, it demonstrates the valorization of agricultural and household waste into high-value chemicals, contributing to the growing field of green chemistry and sustainable resource utilization. Practically, it provides a pathway for low-cost production of fertilizers and industrial inputs, especially in rural or resource-limited settings where access to commercial fertilizers is constrained (Yao et al., 2013). By transforming biomass residues into potassium nitrate, this research contributes to circular economy approaches, environmental sustainability, and local resource management.

Statement of the Problem

Potassium nitrate (KNO_3) is an important chemical with widespread applications in agriculture, food preservation, glass manufacturing, pyrotechnics, and pharmaceutical industries (Moldoveanu & David, 2020). Its dual nutrient composition potassium and nitrogen makes it especially valuable as a fertilizer, since both elements are essential for plant growth and crop yield improvement. However, the commercial production of potassium nitrate relies heavily on industrial synthesis methods that require costly raw materials and controlled conditions, which are often inaccessible in rural and resource limited communities (Demeyer et al., 2001). Furthermore, lack of optimized, low-cost, and environmentally sustainable methods for synthesizing and characterizing potassium nitrate from biomass-derived sources constitutes a major problem. On one hand, vast quantities of wood ash are wasted or improperly disposed contributing to environmental pollution. On the other hand, the high demand for potassium nitrate in agriculture and industry continues to be met through costly industrial synthesis and importation. Bridging this gap through the development of reliable methods for producing KNO_3 from wood ash could provide a dual benefit of waste valorization and local production of a vital chemical resource (Chaturvedi & Dave, 2013).

The aim of this study is to synthesize and characterize potassium nitrate salt from wood ash and nitric acid. The objectives of this study include:

1. To extract potassium carbonate (K_2CO_3) from wood ash.
2. To concentrate the wood ash extract by double boiling.
3. To produce potassium nitrate (KNO_3) from wood ash extract and nitric acid (HNO_3) using neutralization method.
4. To evaporate the aqueous solution to dryness.
5. To dry the moist potassium nitrate (KNO_3) salt in hot air oven.
6. To characterize the dried potassium nitrate salt.

Research Questions

- i. What conditions maximize potassium extraction from wood ash?
- ii. Can extracted potassium be effectively converted into KNO_3 using HNO_3 ?
- iii. What are the major impurities in the product?
- iv. Does characterization confirm synthesis of crystalline KNO_3 comparable to standard references?

Scope and Limitations of the Study

This study covers laboratory-scale leaching of wood ash, synthesis of KNO_3 using nitric acid, crystallization, and characterization. It does not address large-scale industrial production. Limitations include variability in ash composition, limited availability of advanced purification methods, and reliance on the instrumentation available

Significance of the Study

The research provides a sustainable approach to transforming wood ash into a useful chemical, thus reducing waste while producing fertilizers or industrial raw materials (Misra et al., 1993). It also contributes to scientific knowledge on resource recovery, small-scale saltpetre production, and waste to resource conversion, which is vital for rural and developing communities (Yao et al., 2013).

Materials and Methods

Sample Collection and Processing

Wood ash samples were collected from Tambu and tawalala Daura. Approximately 1–2 kg of ash was obtained from each source, labeled with the date, source, and stored in airtight polyethylene bags to prevent moisture absorption and contamination. The collected ash was first air-dried for several hours and then oven-dried at 105 °C for 2 hours to remove residual moisture and ensure consistent weight measurement. The dried ash was sieved through a 2 mm mesh to remove unburned particles, stones, and other debris, followed by grinding with a mortar and pestle to achieve a uniform particle size of less than 500 μm , thereby increasing the surface area available for efficient extraction of soluble potassium compounds. Homogenized ash samples were stored in sealed containers prior to experiment and personal protective equipment, including gloves, dust masks, and goggles, were used to prevent inhalation of ash dust and skin contact with potential irritants, ensuring laboratory safety.

Extraction of Potassium based alkaline from Wood Ash

The potassium based alkaline was extracted from wood ash using a procedure described in Ogunsuyi and Akinnawo, 2012, with little modification. The extraction of potassium carbonate was performed by weighing 150 g of the processed ash into a 2 L beaker, followed by the addition of 1000 mL of distilled water, achieving a 1:10 ash-to-water ratio suitable for effective leaching of soluble potassium species. The mixture was heated to 100 °C on a water bath (digital model) while being heated continuously for 1 hour to maximize the dissolution of potassium compounds, primarily K_2CO_3 , along with minor quantities of KOH and KCl. The slurry was allowed to settle for 30 minutes to separate insoluble residues, after which it was filtered using Whatman No.1 filter paper to obtain a clear filtrate. To enhance potassium recovery, the extraction process was repeated three times; and the combined filtrates were monitored for pH, which ranged from 10 to 13, confirming the alkaline nature of the solution. Observations revealed a clear to slightly yellow solution, indicating successful leaching of soluble potassium compounds. This step was crucial in minimizing co-extracted insoluble impurities and ensuring a reproducible starting solution for nitration, while all procedures were performed with appropriate Personal Protective Equipment to prevent exposure to the alkaline solution. (Ogunsuyi and Akinnawo 2012)

Nitration Reaction of Wood Ash Extract Using Nitric Acid

The filtrate obtained from the extraction step was transferred to a 2 L beaker and placed in an ice bath to maintain the temperature between 5–10 °C, which minimized the exothermic reaction during acid addition. 0.1M nitric acid was added slowly to the filtrate under continuous stirring, with careful observation of effervescence resulting from CO_2 release during the neutralization of potassium carbonate. Acid addition continued until the solution reached a neutral pH 7, after which stirring was maintained for an additional 30 minutes to ensure complete reaction. Insoluble residues, primarily silicates and unreacted ash particles, were removed by filtration, yielding a clear solution containing potassium nitrate. Observations included cessation of effervescence and increasing clarity of the solution, indicating successful conversion of potassium compounds to KNO_3 . All steps were performed in a fume hood with appropriate personal protective equipment, and any accidental acid spills were neutralized immediately using sodium bicarbonate, highlighting the importance of safety in handling corrosive acids. (Sheaths and Adhikari 2018, Iqbal et al, 2018 and Journals et al, 2019).

Evaporation of Aqueous Solution of Potassium Nitrate to Dryness

The potassium nitrate solution was transferred into an evaporating dish and heated gently at 50–70 °C on water-bath (digital model) to evaporate the water, avoiding vigorous boiling that could lead to splattering or inclusion of impurities. The concentrated solution was allowed to cool slowly at room temperature, followed by further cooling in an ice bath to induce crystallization. The formed KNO_3 crystals were collected by vacuum filtration and rinsed with a minimal volume of cold distilled water to remove residual liquor without significant product loss. The crystals were then dried in an oven (Labmet LMHO-B102) at 50–60 °C until a constant mass was achieved, and the percentage yield was calculated based on the initial

potassium content of the ash. Observations revealed the formation of light brown, prismatic crystals. Safety measures include careful monitoring of heating to avoid decomposition of nitrate and proper neutralization of residual filtrates before disposal, ensuring environmental compliance.

Characterization of Potassium Nitrate

Physical Parameters

Some physical parameters of the newly synthesized potassium nitrate salt were determined. These parameters include physical appearance (color), odor, solubility in water and ethanol, density, and melting point using melting point apparatus.

Density Determination

The true density determination of the sample was performed using Archimedes principle. 1.0g of dried sample wrapped in a polyethene was immersed in water. The water level before and after immersion was recorded. The density was evaluated by dividing dried weight and the difference in water level before and after immersion.

Determination of PH

The pH of the sample was determined by soaking the solid formulated sample in water and the pH measured using Hanna pH meter (Model HI 98128).

Determination of Organic Matter Contents

These were determined by burning the oven dried sample at a temperature of 350°C for 3 hours. The total organic matter was calculated from the difference between weight of oven dried sample before and after burning.

Chemical Compositions

The chemical compositions of the developed potassium nitrate were recorded from a monitor attached to an energy-dispersive X-ray fluorescence machine of model Genius-IF Xenometric EDXRF, Skyray Instruments, USA. The sample film was placed firmly in a waxed and gold-plated sample holder. The energy dispersive patterns were obtained with the help of a computer attached to the instrument and each compound recorded in percentage. (Jock and Illechukwu, 2023)

Table 1: Physical Parameters of Potassium Nitrate

Parameters	Results
Appearance	Light brown crystals
Odor	Odorless
Solubility	Soluble in water and insoluble in ethanol
Density at 25°C (g/cm ³)	2.10
Melting point. (°C)	329
PH	6.1

Results and Discussion

Physical Properties of the Synthesized Potassium Nitrate

The physical properties of the sample are presented in Tables 1. The physical analyses determined on the sample were density, pH, appearance, odor, solubility and total organic matter. The potassium nitrate has the pH of 6.1, which shows that sample is weakly acidic in nature. This also indicates that sample C will be effective in neutralizing a basic soil. The density value was found to be $2.1\text{g}/\text{cm}^3$. This value is nearly equal to that commercially manufactured potassium nitrate. With regard to solubility, the sample is soluble in water but not in ethanol. This is because the sample is purely inorganic compound. The color of the sample is light brown, which is not in line with the color of commercial potassium nitrate. This may be attributed to presence of impurities from the wood ash. The remaining physical parameters are in line with that of pure potassium nitrate.

Table 2: Chemical Composition of the Sample

Components	Composition (%)
K	10.010
N	12.251
CaO	25.321
P ₂ O ₅	0.401
MgO	1.321
Na ₂ O	1.134
Total Organic Matter	47.542

The chemical analyses of the sample (potassium nitrate) are shown in Tables 2. The chemical analysis (weight %) shows that some components in the samples occur in trace and minor amounts while other components are occurring in major quantity. The content of macro-elements in the sample are N (12.251%), P₂O₅ (0.401%), K (10.010%), CaO (25.321%), MgO (1.321%), Na₂O (1.134%) and organic matter (47.542%) appear in major amount. This may be from the chemical constituents of the wood as used in the synthesis. Increased in soil organic matter also increases the degree of aggregation and pores volume (Loss et al., 2019). However, the temperature (100°C) used for drying the sample may lead to vaporizing some of the essential elements such as nitrogen, phosphorous, etc. (Monastyrskiy et al. 2022). Generally, the chemical analysis indicated that the weight percentage of different elements like nitrogen, phosphorus, potassium, and calcium are within the required range and this suggested that this fertilizer is a good source of nutrition which can promote the growth of the plant (Majeed et al. 2020)

Conclusion and Recommendations

The purpose of this research is to synthesize and characterize potassium nitrate salt from wood ash extract and nitric acid. The extraction process confirmed that wood ash is a feasible, cheap source of potassium tioxocarbonate (K₂CO₃), which reacted effectively with the acid to yield

pure crystals of potassium nitrate. Characterization of the final product revealed the physical and chemical properties in line with analytical-grade potassium nitrate. The results indicate that utilizing wood ash not only provides a sustainable alternative to synthetic potassium sources but also offers an eco-friendly waste management solution. Therefore, this study explored a feasible and cost-effective approach for the small-scale production of the nitrate-based fertilizers. Based on the findings of this study, the following recommendations were made:

1. **Purification Improvement:** The crude potassium nitrate should be further purified through hot-water recrystallization and activated-charcoal treatment to remove residual metal oxides and organic matter that cause discoloration and minor impurities.
2. **Agronomic Evaluation:** Field and greenhouse trials should be conducted to assess the fertilizer efficiency, nutrient release pattern, and effects on different soil types and crops to establish the product's agronomic value and safety for large-scale agricultural use.
3. **Process Optimization:** Further studies should focus on optimizing reaction parameters such as temperature, concentration of nitric acid, reaction time, and purification technique to improve yield, reduce impurity levels, and ensure consistent product quality. Finally, the study is significant because it successfully transformed and abundant agricultural waste product into a valuable fertilizer and industrial reagent, promoting sustainable conversion of waste to wealth.

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