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Cluster Fig (Ficus racemosa) Ash: A Greener Alternative to Conventional Strong Bases

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ABSTRACT

The exploration of plant-derived materials for sustainable applications has gained significant attention in green chemistry and environmental sciences. This study investigates cluster fig (Ficus racemosa) ash as a novel, eco-friendly alternative to conventional strong bases. The ash, obtained through controlled calcinations of cluster fig biomass, exhibits high alkalinity due to its rich composition of alkaline metal oxides and carbonates. Its potential as a biogenic base is demonstrated through various organic transformations, highlighting superior catalytic efficiency, recyclability, and reduced environmental impact compared to synthetic bases such as NaOH and KOH. This research underscores the importance of plant-derived waste valorization, offering a sustainable approach to replacing conventional bases with renewable botanical resources.

INTRODUCTION

The increasing concern over environmental pollution and sustainability has driven researchers to explore eco-friendly alternatives to conventional chemical reagents. Inorganic strong bases such as sodium hydroxide (NaOH) and potassium hydroxide (KOH) are widely used in various industrial and laboratory applications, but their excessive use leads to environmental hazards, including water pollution and soil degradation. As a result, there is a growing interest in plant-derived alkaline materials that can serve as sustainable substitutes for conventional strong bases[1-10]. One such promising source is Ficus racemosa fruit, commonly known as the cluster fig, which is known for its medicinal, ecological, and traditional significance[11-15]. The ash derived from its biomass could offer an environmentally benign and renewable alternative to synthetic alkaline reagents.

Cluster fig is a deciduous tree belonging to the Moraceae family and is widely distributed across India, Southeast Asia, and Australia. Various parts of this plant, including its bark, leaves, fruits, and latex, have been extensively used in traditional medicine due to their therapeutic properties. Additionally, the tree has been recognized for its ecological benefits, such as soil stabilization and carbon sequestration. The combustion of cluster fig biomass yields an ash rich in alkaline minerals like calcium, potassium, and magnesium, making it a valuable candidate for applications requiring alkaline media. This natural ash can serve as an alternative to industrially produced strong bases in fields such as agriculture, organic synthesis, and wastewater treatment.

The use of cluster fig ash as a base aligns with the principles of green chemistry by reducing the dependence on synthetic chemicals and promoting the utilization of waste biomass. Unlike commercial bases that require energy-intensive production processes, plant-based ash can be easily obtained through controlled combustion with minimal environmental impact. Moreover, the alkaline components in cluster fig ash are naturally occurring and biodegradable, further enhancing its sustainability. Research into plant-derived ashes has shown that they can effectively catalyze organic reactions, enhance soil fertility, and even serve as adsorbents for pollutants, indicating the broad applicability of such materials.

This paper aims to explore the physicochemical properties of cluster fig ash, its alkaline nature, and its potential applications as a greener alternative to conventional strong bases. By analyzing its composition and effectiveness in various biological and chemical processes, we seek to highlight its advantages over traditional reagents. The findings of this study will contribute to the broader understanding of plant-derived alkaline materials and their role in promoting sustainable scientific and industrial practices

Experimental:

Preparation and characterization of the CFA

The fresh matured Ficus racemosa fruit were collected from ficus tree, these collected fruit was cleaned and dried then cut into small pieces add this (5.0 g) pieces in clean dry silica crucible and burned into the furnace at 400^{0}C, then the obtained soft ash is CFA catalyst. The alkalinity of CFA in water was measured 0.5 gm of cluster fig ash in 10 ml of water this solution shows pH 12 it indicates strongly alkaline nature of catalyst.

3. Result and discussion

3.1 XRD of CFA catalyst

The characteristic peak at 2θ = 24.62°, 30.46°, 31.44°, 34.48°, 39.31°, 44.93°, 52.18° represents the planes (111), (-112), (130), (131), (132), (200), (220) (Fig.3). Standard data evaluation JCPDS (File No. 77-0211) confirmed that the prepared catalyst is enrich with potassium as a alkali metal.

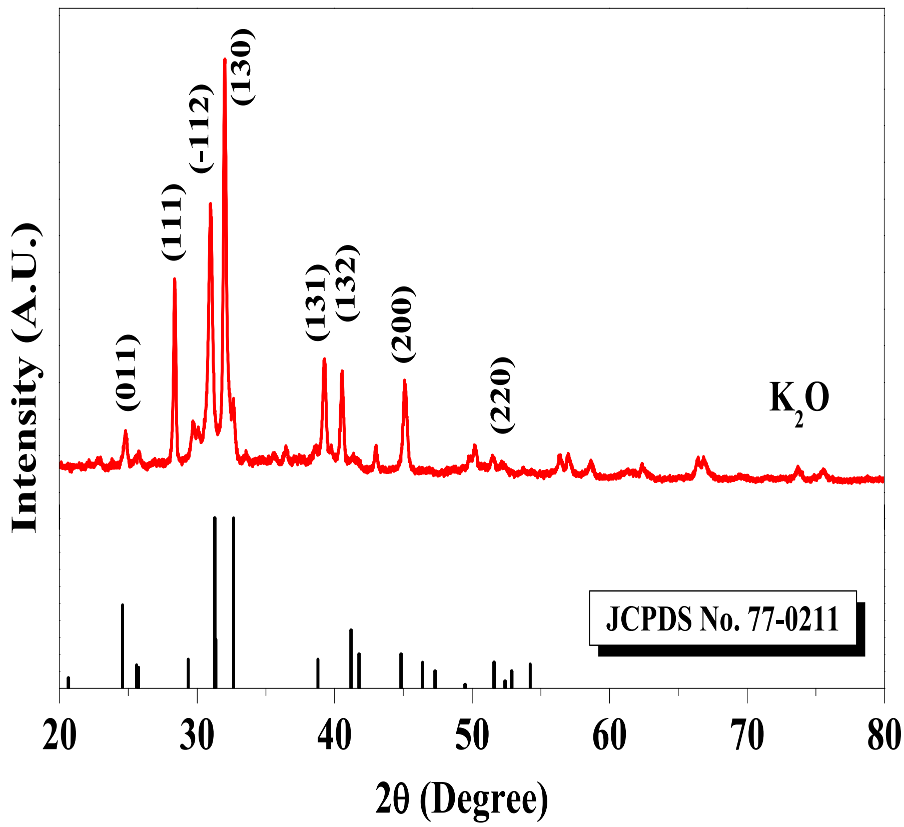


Fig.3.1 XRD spectrum of Cluster Fig ash.

3.2 FTIR

In the FTIR spectrum of CFA catalyst (Fig.3.2), shows absorption bands at 484, 1022, 1411, 2943 cm^{-1} corresponds to carbonates, and the band at 1653 cm^{-1} demonstrates carbonyl group from carbonate. Also the stretching broad band at 3426 cm^{-1} correlates presence of hydroxyl group in the spectrum of CFA catalyst, which encourage the formation of metal hydroxide by absorption of moisture from the environment.

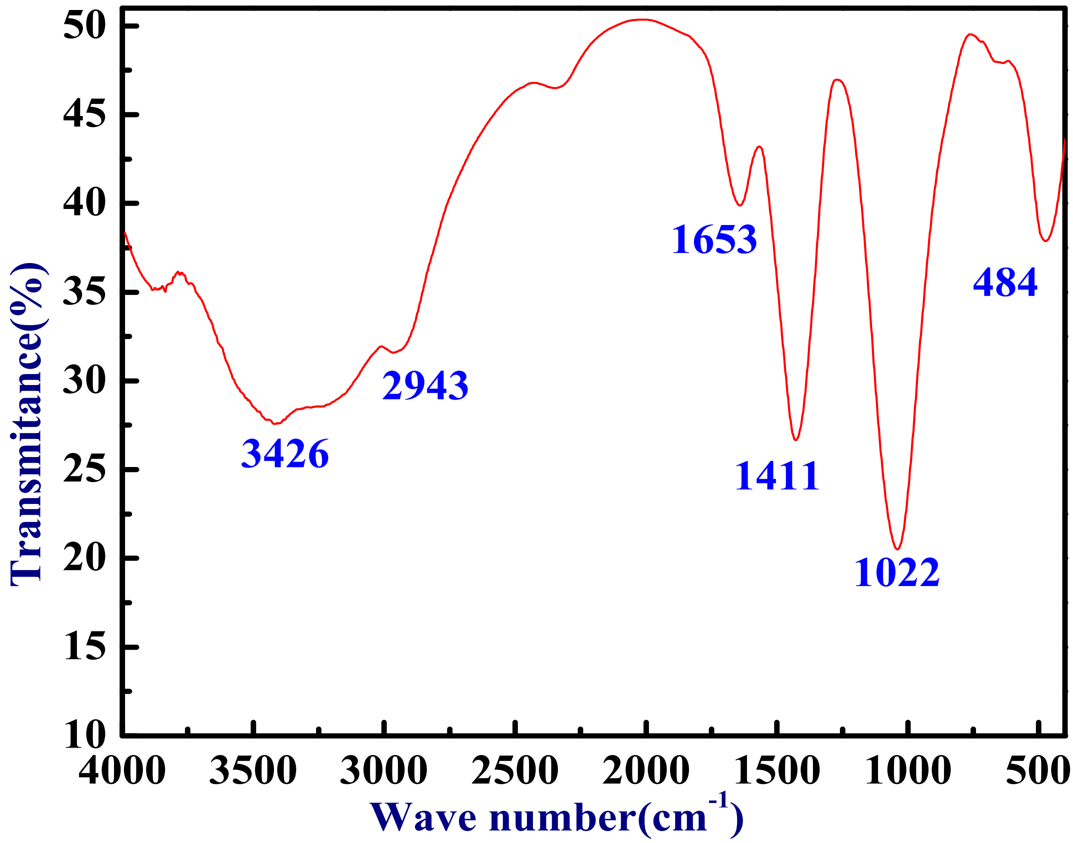


Fig.3.2 IR spectrum of Cluster Fig ash.

3.3 SEM

Scanning electron microscopy (SEM) was used to examine the shape and surface morphology CFA catalyst. SEM images show that the catalyst is porous and provides an uneven surface area that helps to promote the reaction. (Fig.3.3).

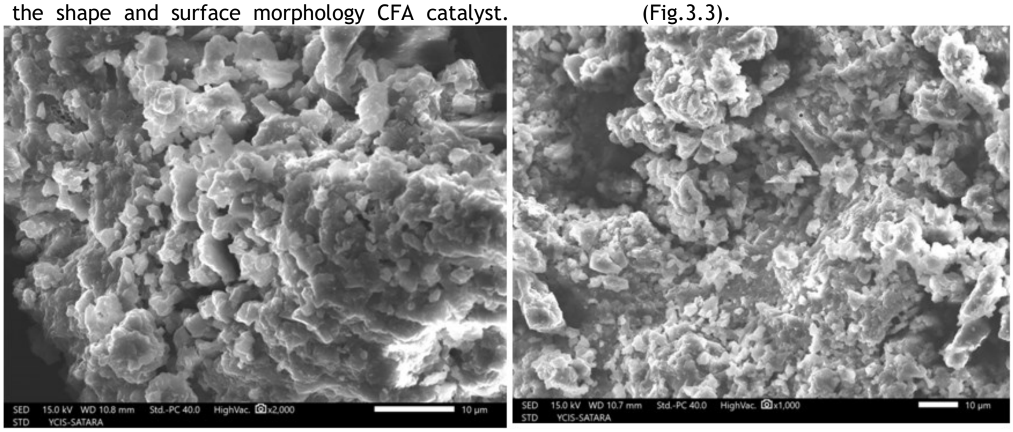
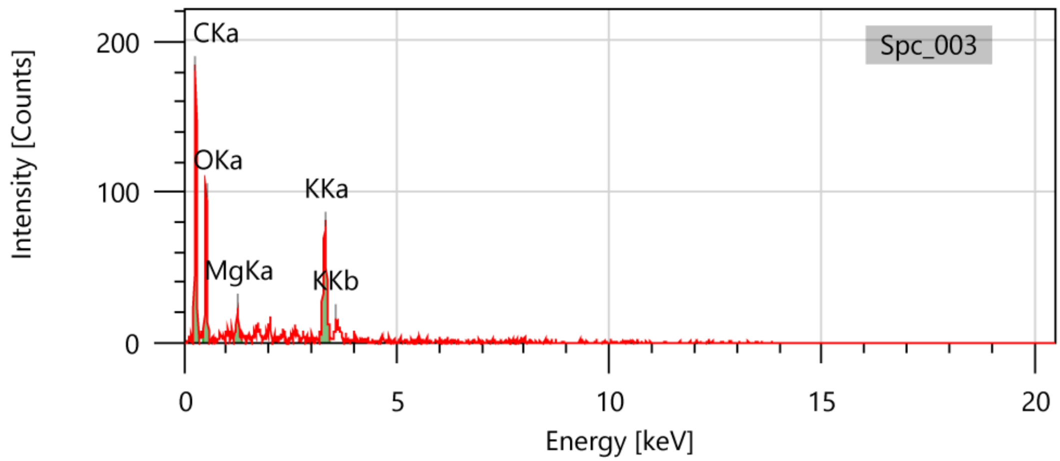


Fig.3.3 SEM Images of Cluster Fig ash.

3.4 EDX

The EDX analysis illustrates the chemical composition of the CFA catalyst. The catalyst is made up of the elements C, O, Mg, and K; no other elemental impurities exist according to the EDX evaluation. The C, O, Mg, and K includes of the CFA catalyst were satisfactorily explained by the elemental mapping displayed in (Fig.3.4). The strong basic character of the catalyst is confirmed by the existence of these alkali and alkaline earth metals.



Display name	Standard data	Quantification method	Result Type
Spc_003	Standardless	ZAF	Metal

Element	Line	Mass%	Atom%
C	K	38.21±0.68	50.81±0.90
O	K	39.90±1.65	39.84±1.65
Mg	K	1.66±0.26	1.09±0.17
K	K	20.24±0.98	8.27±0.40
Total		100.00	100.00
Spc_003			Fitting ratio 0.1854

Fig.3.4 EDX spectrum of Cluster Fig Ash.

3.5 TGA:

The prepared catalysts thermal stability was analyzed using DSC-TGA thermal analyzer. **(Fig.3.5)** shows temperature dependant CFA decomposition in specific environment to avoid misleading oxidation chemical reactions. Ash decomposition was observed at 0 to 1000°C temperature. The weight loss of material were shown in Fig. 3.6 in the primary stage, the minor 1.4% weight loss was seen below the 204 ^{0}C and it is because of adsorbed moisture. In the secondary stage 0.4% and in tertiary stage1.8% weight loss was due to degradation of organic molecules like carotenoids, alkaloids, pectins, tannins, flavonoids, terpenoids, and chlorides, it was observed at 204 ^{0}C to 627^{0}C and 627 ^{0}C to 930 ^{0}C temperatures. Finally 95.4% of residue remaining after the temperature of 1000^{0}C was due to metal oxides.

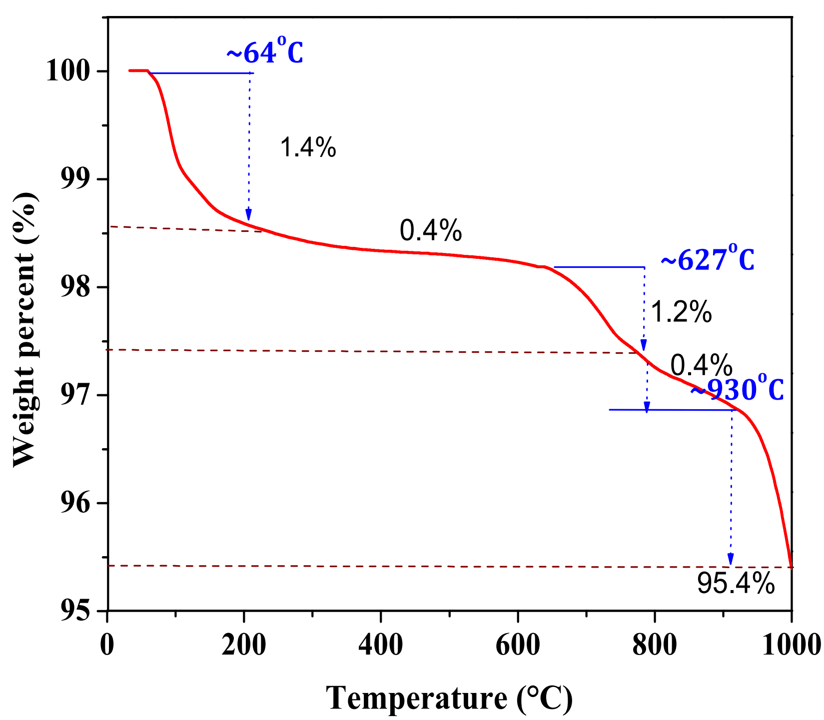


Fig.3.5 TGA of Cluster fig ash.

CONCLUSION

The study of Cluster Fig ash as a greener alternative to conventional strong bases highlights its potential as an eco-friendly, sustainable, and cost-effective alkaline material. Rich in essential alkaline earth metals like calcium, potassium, and magnesium, the ash offers promising applications in agriculture, organic synthesis, and environmental remediation while reducing dependence on hazardous chemical bases. Its natural abundance and minimal environmental impact align with the principles of green chemistry and sustainable resource utilization. Further research on its physicochemical properties and broader applicability will enhance its role as a viable botanical alternative in various scientific and industrial fields.

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Disclosure statement

The authors declare no conflict of interest.

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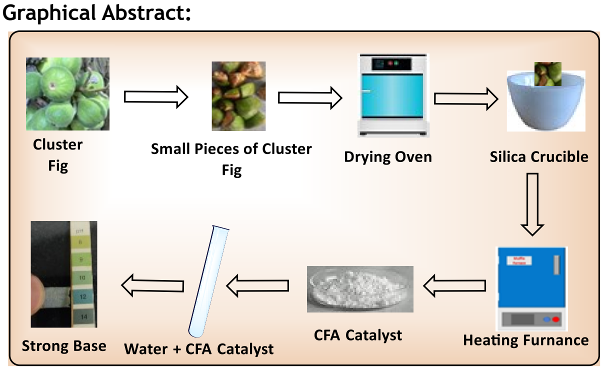
Graphical Abstract:



The graphical abstract illustrates the conversion of cluster fig (Ficusracemosa) into an environmentally benign strong base catalyst. Initially, the cluster figs are cut into small pieces and dried in an oven to remove moisture. The dried material is then subjected to high-temperature heating in a furnace using a silica crucible, leading to the formation of a carbon-based catalyst (CFA Catalyst).

The obtained catalyst is mixed with water to activate its strong base properties, which is confirmed using pH testing. This process highlights the sustainable approach of utilizing biomass waste for developing eco-friendly catalytic materials.