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A Comprehensive Review of Banana Fiber-Reinforced Composites:Properties, Processing and Applications

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Abstract

Banana fiber-reinforced composites are a promising area of research due to their sustainable and renewable nature and physical and mechanical properties. This comprehensive review article analyzed the physical structure, chemical composition, and mechanical properties of banana fibers and the processing methods and challenges associated with their use. The review also covers the different variants of banana fiber-reinforced composites, including their thermal and mechanical properties, current and future applications, and the implications for researchers, engineers, and manufacturers interested in exploring the potential of these materials. The study found that the mechanical properties of banana fiber composites depend on various factors, such as fiber length, diameter, and loading, as well as the type of matrix used. However, more research is needed to understand the full potential of banana fiber-reinforced composites and to address challenges such as the inconsistent quality of fibers and the lack of standardization in processing methods. Despite these challenges, the review highlights the potential for these composites to play an important role in sustainable and eco-friendly construction and manufacturing applications.

Keywords: Banana Fiber-Reinforced Composites; Mechanical Properties; Thermal Properties; Processing Techniques; Sustainable Applications

1 Introduction

The use of composite materials has been increasing in many applications in recent years due to their unique properties and ability to tailor them to specific requirements [1]. Among the various types of composite materials, natural fiber-reinforced composites have been gaining considerable attention due to their environmental and economic benefits over traditional glass fiber composites [2]. These composites combine natural fibers, such as flax, hemp, jute, and kenaf, with polymer matrixes to form a material that combines the properties of both components [3]. Banana fiber, in particular, has emerged as a promising alternative among natural fibers due to its low density, high strength, and biodegradability [4–6]. Banana fibers are obtained from the banana plant's pseudostems, a waste product of the banana industry [7]. They can be extracted by simply retting, washing, and drying, making them widely available and cost-effective [8].

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The mechanical properties of banana fibers are comparable to those of glass fibers, making them suitable for reinforcement in composite materials [9]. The need for sustainable and eco-friendly materials in various industries drives the growing interest in banana fiber-reinforced composites [10]. These composites have been explored for use in applications such as automotive parts, construction materials, packaging, and agriculture [11]. However, there is a lack of comprehensive and up-to-date reviews on the current state-of-the-art in banana fiber-reinforced composites, including their properties, processing techniques, and diverse applications. The properties of banana fiber composites are affected by various factors, including fiber configuration, length, orientation, and surface treatments. The fiber configuration refers to the arrangement of fibers in the composite, which can be in the form of mats, woven fabrics, or randomly oriented fibers. The length of the fibers plays a crucial role in the mechanical properties of the composite, with longer fibers providing higher strength and stiffness. The orientation of the fibers also affects the properties, with fibers oriented in the direction of the applied load providing the highest strength. Surface treatments, such as chemical modification, can also be applied to the fibers to improve their compatibility with the polymer matrix and enhance their properties. The curing process hardens the polymer matrix and creates a stable composite material. [12–17].

The processing techniques for banana fiber composites include extracting and preparing the fibers, fabricating the composites, and curing the polymer matrix. The fibers can be extracted from the pseudo-stems of the banana plant by a simple process of retting, washing, and drying. The fibers are then prepared by cutting them to the desired length and removing any impurities. Various methods can fabricate the composites, including hand layup, compression molding, and injection molding [18–21]. The applications of banana fiber composites are diverse and include automotive parts, construction materials, packaging, and agriculture. Automotive parts made from banana fiber composites have been shown to have high strength and stiffness, making them suitable for use in load-bearing applications. In the construction industry, banana fiber composites have been used as insulation materials and as a substitute for timber in decking, flooring, and roofing applications. Packaging made from banana fiber composites is biodegradable, making it an environmentally friendly alternative to traditional packaging materials. In agriculture, banana fiber composites have been used as plant supports and as a substitute for synthetic materials in irrigation systems [20, 22–27]. This review article aims to provide a comprehensive and up-to-date overview of the current state-of-the-art in banana fiber-reinforced composites, including their properties, processing techniques, and diverse applications. The article will also delve into the various factors that affect the properties of banana fibers, such as fiber configuration, length, orientation, surface treatments, and environmental conditions. A detailed comparison of banana fiber composites with other natural and synthetic fibers will also be provided. Furthermore, the article will highlight the challenges and opportunities for future research in this field. This review aims to provide valuable insights for researchers, engineers, and manufacturers interested in exploring the potential of banana fiber-reinforced composites as a sustainable alternative in various industries.

2 Banana Fibers

2.1 Physical structure and chemical composition

Banana fiber, also known as banana silk, is a type of natural fiber obtained from the stem of the banana plant. The fiber is obtained from the stem's inner layers, known as the pseudo-stem. The pseudo-stem comprises long, tightly packed and woven fibers [8]. These fibers are about 3-5 meters long and have a diameter of about 0.15-0.3mm [5]. The structure of the banana fiber is unique and comprises cellulose, hemicelluloses, and lignin. Cellulose is the main component of the fiber and provides it with strength and durability. Hemicelluloses, on the other hand, contribute to the elasticity and flexibility of the fiber. Lignin, the third component, helps strengthen the fiber's cell walls and provides a rigid structure [28, 29]. The fibers are harvested from the stem of the banana plant when it reaches maturity. The stem is stripped of its outer layers, and the inner fibers are extracted by peeling or cutting. The fibers are then washed, dried, and sometimes treated with chemicals to remove impurities and improve their quality [8, 12, 30]. Banana fiber is characterized by its strength, durability, and versatility. It is known for its ability to resist abrasion and breakage, making it suitable for various applications in the textile industry [31–33]. The fiber is also known for its natural shine and soft texture, making it comfortable to wear and use in various products. In terms of its use, banana fiber is typically used in producing textiles such as clothing, upholstery, and accessories [34–36]. It is also used to manufacture paper products, ropes, and baskets [20, 37–39]. In some countries, it is even used in the construction industry as a substitute for asbestos [40–42]. Table 1 shows the various cells found in fiber of varying diameters [43, 44].

Table 1: The number of various cells and helix angle of banana fibers for various diameters [43, 44].

Diameter of Fiber (μm)	Average Number of Xylem Cells	Average Number of Phloem Cells	Average Number of Sclerenchyma Cells	Total Number of Cells	Helix or Microfibrilar angle (Φ)
100	3	6.25	53	62.25	12
150	3	8.00	70	81.00	11
200	4	7.75	92	103.25	11

The chemical structure of the banana fiber is complex and multi-layered, with three main components that determine its physical and mechanical properties. These components are cellulose, hemicellulose, and lignin [45–47]. Cellulose is a complex carbohydrate that forms the main structural component of banana fiber. It is a linear polymer made up of repeating units of glucose and is responsible for the strength and rigidity of the fiber. Cellulose gives banana fiber high tensile strength and modulus of elasticity, making it ideal for various applications, including textiles, paper, and construction materials [48–50].

Hemicellulose is a complex mixture of polysaccharides that acts as a binding agent between the cellulose fibers [51, 52]. It is responsible for the elasticity and flexibility of the fiber and provides a cushioning effect. Hemicellulose helps to absorb shocks and protect the cellulose fibers from breaking or tearing, making it an important component of banana fiber's overall strength and durability [53–55].

Lignin is a complex organic polymer that acts as a cementing agent, binding the cellulose and hemicellulose fibers together. It provides the fiber with rigidity and toughness, making it resistant to breakage and damage. Lignin also provides banana fiber with its natural brown color, making it suitable for various applications, including textiles and paper products [56–58].

In addition to the three main components, banana fiber contains small amounts of other organic compounds, including waxes, pectins, and tannins [59, 60]. These compounds play a role in the overall chemical composition of the fiber and contribute to its unique properties, including its moisture resistance and durability. Table 2 and Table 3 detail the chemical and physical properties of various cellulosic fibers [**?** 61, 62]. These compounds play a role in the overall chemical composition of the fiber and contribute to its unique properties, including its moisture resistance and durability. Overall, the chemical structure of the banana fiber is highly complex, with a combination of linear polymers, binding agents, and other organic compounds that contribute to its unique physical and mechanical properties. This combination of components makes banana fiber a highly versatile and useful natural resource widely used in various industries, including textiles, paper, and construction.

Table 2: Metal elements present as ions in cellulosic fibers [44].

Fiber	Al^{3+}	Ca^{+}	Mg^{+}	Na^{+}	Si^{4+}
Banana	0.141	5.721	1.771	0.280	1.410
Coconut	0.031	2.440	0.760	2.530	2.561
Bagasse	3.891	3.870	1.320	0.971	27.001

Table 3: Properties of natural cellulosic fibers [61, 62].

Fibers	Composition in percentage weight						
	Lignin	Cellulose	Hemicellulose	Moisture content	Carbon content	Water Absorption	Ash content
Banana	9.00	43.46	38.54	85.60	8.30	50.90	40.10
Coconut	59.40	32.65	7.95	27.10	5.10	51.50	169.10
Bagasse	13.00	30.27	56.73	52.20	4.50	53.10	235.10

2.2 Mechanical properties

The mechanical properties of the banana fiber are an important factor that determines its suitability for various applications, such as textiles, paper, and construction materials. These properties include its tensile strength, modulus of elasticity, elongation at break, and toughness. Tensile strength refers to the maximum stress that a material can withstand before breaking [63]. Banana fiber has high tensile strength, making it suitable for high-strength and durability applications. This strength is due to the presence of cellulose, which acts as the main structural component of the fiber and provides it with resistance to breaking and tearing. The modulus of elasticity measures a material's stiffness and resistance to deformation.

Banana fiber has a high modulus of elasticity, making it ideal for applications where stiffness and stability are important. This property is largely due to cellulose and lignin, which provide the fiber with rigidity and toughness. Elongation at break refers to the amount of extension a material can undergo before breaking. Banana fiber has a low elongation at break, making it suitable for applications where flexibility and stretch are unimportant. This property is largely due to hemicellulose, which provides the fiber with elasticity and flexibility. Toughness refers to the ability of a material to absorb energy without breaking [63]. Banana fiber has a high toughness, which makes it ideal for use in applications where resistance to breakage and damage is important. This property is due to hemicellulose and lignin, which act as binding agents and provide the fiber with cushioning and protection against shocks and stresses. These properties make banana fiber a highly versatile and useful natural resource widely used in various industries, including textiles, paper, and construction. With its unique combination of properties, banana fiber is well-suited for many applications where high strength, durability, and resistance to breakage are important. The mechanical properties vary with the diameter of the fibers, and the same is depicted in Table 4 [64].

Table 4: Mechanical properties of banana fiber of different diameters [64].

Diameter of Fiber (mm)	Initial Young's Modulus (N)	Breaking Strength (N)	% Strain
50.00	32.70	779.07	2.75
100.00	30.46	711.66	2.46
150.00	29.74	773.00	3.58
200.00	27.69	789.29	3.34
250.00	29.90	766.60	3.24

2.3 Factors affecting the properties of banana fibers

The properties of banana fibers, such as their tensile strength, modulus of elasticity, elongation at break, and toughness, are influenced by various factors. These factors can be divided into two main categories: intrinsic and extrinsic. Intrinsic factors refer to those that are inherent to the structure and composition of the fiber itself. These factors include the type and quantity of cellulose, hemicellulose, and lignin in the fiber and other organic compounds such as waxes, pectins, and tannins. These components determine the overall mechanical and chemical properties of the fiber, and variations in their composition can result in differences in the properties of the fiber. Extrinsic factors refer to those external to the fiber and include factors such as the environment in which the fiber is produced, the harvesting and processing methods used, and the end-use application of the fiber. These factors can have a significant impact on the properties of the fiber and can result in differences in the fiber's strength, stiffness, and durability [65, 66].

For example, the environment in which the fiber is produced can affect its properties by changing the moisture content of the fiber, which can impact its strength and rigidity [58, 67]. The harvesting and processing methods used can also influence the properties of the fiber by affecting the fiber's structure, composition, and overall quality [68]. In particular, chemical treatments during processing can change the properties of the fiber and make it more or less suitable for certain applications [69]. The end-use application of the fiber can also significantly impact its properties. For example, fibers used in textiles may need to be soft and flexible, while fibers used in construction materials may need to be strong and stiff. These differing requirements can impact the processing and treatment of the fiber, leading to differences in its properties.

3 Processing Techniques for Banana Fiber Composites

Banana fiber composites have gained significant attention recently due to their excellent mechanical properties and potential applications in various fields. However, the processing of banana fiber composites is a complex process that requires a thorough understanding of the properties and behavior of both the fiber and the matrix. This section will discuss the methods for extracting and preparing banana fibers, the techniques for fabricating banana fiber composites, and the current challenges and opportunities in processing banana fiber composites.

3.1 Methods for extracting and preparing banana fibers

The extraction and preparation of banana fibers are crucial steps in processing banana fiber composites. The fibers are extracted from the banana pseudo-stem, the stem-like structure supporting the banana fruit. The fibers are separated from the rest of the pseudo-stem by a process known as decortication. This can be done manually by peeling the fibers away from the stem or using machine-assisted methods. Once the fibers have been extracted, they are usually washed to remove any impurities, such as dirt, sap, or pith. The fibers are then dried to reduce their moisture content, which is important for preventing mold growth and ensuring the stability of the composites. The dried fibers are cut into small pieces, and their length and diameter are measured [70–72].

3.2 Techniques for fabricating banana fiber composites

Several techniques for fabricating banana fiber composites include hand layup, compression molding, injection molding, and filament winding. The most common technique is hand layup, where the fibers are manually placed into a mold and resin is applied using a brush or roller. The mold is then closed, and the composite is cured under pressure and heat. Compression molding is another popular technique for fabricating banana fiber composites. In this process, the fibers and resin are placed into a preheated mold, and the mold is then compressed to produce the final composite. Injection molding is a more complex process where the fibers and resin are fed into an injection molding machine, and the composite is formed under high pressure. Filament winding is a technique that is often used for producing high-performance composites, such as those used in aerospace and sports equipment. In this process, the fibers are wound around a mandrel, and resin is applied to the fibers as they are being wound. The composite is then cured under heat and pressure.

3.3 Current challenges and opportunities in processing banana fiber composites

Several challenges are associated with processing banana fiber composites, including the fibers' variability, high moisture content, and the need for specialized equipment. The variability of the fibers can result in differences in the composites' mechanical properties, making it difficult to produce composites with consistent properties. The high moisture content of the fibers can also be a challenge, as it can cause the fibers to degrade over time and reduce the strength of the composites. The fibers must be thoroughly dried before they are used in composites. The composites must be stored in a dry environment to prevent moisture from affecting their properties and overcome degradation. Another challenge is the need for specialized equipment to process banana fiber composites. This includes equipment for extracting and preparing the fibers and specialized molding and curing equipment. The cost of this equipment can be a barrier for some companies, especially those in developing countries where banana fiber is abundant. Despite these challenges, there are also many opportunities for processing banana fiber composites. One opportunity is the development of new techniques for extracting and preparing more efficient and cost-effective fibers. This could help reduce the fibers' variability and improve the composites' quality. Another opportunity is the development of new fabrication techniques that can improve the mechanical properties of the composites and make them more suitable for a wider range of applications. This could include the development of advanced composite processing techniques, such as those used in the aerospace and sports equipment industries. In addition, there is a growing interest in using sustainable materials in various industries, and banana fiber composites are a promising alternative to traditional synthetic composites. This has led to increased research and development in banana fiber composites, and there is potential for new applications to be discovered.

4 Variants of Banana Fiber Composites

4.1 Banana fiber-reinforced thermoplastic composites

Banana fiber-reinforced thermoplastics have been extensively studied due to their attractive mechanical and thermal properties. Upon heating above their glass transition temperature (Tg) or melting point, thermoplastic polymeric matrices (TPPMs) soften, allowing for reshaping while retaining high strength and toughness, chemical resistance, good durability, self-lubrication, transparency, and waterproofing [73, 74]. Studies by researchers such as Sapuan, Habibi, Paul, and Zainuddin have investigated using banana fibers as reinforcements in thermoplastics [73–77].

4.2 Banana fiber-reinforced thermoset composites

Thermosetting polymeric matrices (TSPMs) are known for their permanent hardness and rigidity due to cross-linked networks of covalent intermolecular linkages between polymer chains. They have superior electrical and thermal insulation properties, chemical resistance, and high tensile strength [75, 78, 79]. Many researchers have documented the integration of banana fiber with TSPMs, including phenol formaldehyde composites [80–90].

4.3 Banana fiber-reinforced cement composites

Banana fiber-reinforced cement composites have been extensively studied in recent years. According to Zhu et al. [40], using banana fiber in cement reinforcement showed promising results. The researchers studied air-cured banana fiber-reinforced cement composites and found that a fiber loading of 14% by mass resulted in a flexural strength of around 25 MPa and a fracture toughness of 1.74 kJ/m2 [40, 91, 92].

4.4 Banana fiber-reinforced biodegradable composites

Kumar et al. [93] explored using banana fiber and soy protein as a matrix for green composites. They mixed alkali-treated and untreated fiber into soy protein isolate (SPI) with different glycerol concentrations (22-50%) as a plasticizer. The results showed that the tensile strength and modulus of the alkali-treated fiber reinforced with soy protein composites increased to 82% and 96.3%, respectively, at a volume fraction of 0.3. Moreover, the biodegradability test indicated that the composites were 100% biodegradable. Another study used Tamarind Seed Gum as the matrix with banana fiber as reinforcements. The resulting tensile strength was 3.97 MPa. The roasting temperature affected the tamarind seed's tensile strength, with the highest tensile strength obtained at 130 degrees Celsius [94].

5 Mechanical and Thermal Properties of Banana Fiber Composites

5.1 Mechanical properties

The mechanical performance of banana fiber-reinforced polymer matrix composites and their applications have been the subject of numerous investigations [88, 89, 95, 74, 96, 81, 13, 97]. These studies have investigated various aspects of banana fiber-reinforced composites, including the effects of fiber weight and length, hybridization with other materials, and the suitability of banana fiber composites for various industries.

5.2 Thermal properties

The thermal conductivity and diffusivity of banana fiber-reinforced polypropylene (P.P.) composites have been studied with various fiber weight percentages and treatments [76, 98–104]. These studies have shown that the addition of nano clay and other treatments can significantly improve the thermophysical characteristics of these composites. The observations made by various researchers concerning the thermal and mechanical properties of Banana Fiber Reinforced Composites are consolidated in Table 5.

Table 5: Consolidated observations on thermal and mechanical properties of banana fiber reinforced composites.

Author(s)	Composite Specifications	Observations
Pothan et al. [89, 95]	Banana Polyester reinforced composite. Banana Fiber reinforced polyester composites	The combination of 40% wt and 30 mm fiber length significantly increases mechanical strength and moisture absorption. Banana fiber with 40%wt and treated with NaOH reduces stress compared with other cases.
Maleque et al. [74]	Pseudo-stem banana weaved fabric reinforced epoxy composites	Reinforcing with epoxy raised the tensile strength by 90% and impact strength by 40%.
Marriati et al. [96]	Woven banana fiber and pandanus fiber reinforced polyester composites produced by vacuum bagging technique	Woven banana fiber has better impact and flexural properties than pandanus fiber.
Haneefa et al. [81]	Glass fiber hybridized with banana fiber	Raising the fiber weight percentage increased tensile and flexural strength.
Biswal et al. [98]	Banana Fiber with Polypropylene matrix and added nano clay	Thermal Stability and Tc value increase significantly.
Kulkarni et al. [102]	Banana Fiber hybrid composites with fly-ash and polypropylene fillers	Improved mechanical and thermal properties.
Mohan et al. [103]	Banana Fiber reinforced with nano clay and treated with NaOH	18% increase in high-temperature deterioration.
Taj et al. [105]	Banana Fiber with Polylactic acids prepared by melt bending technique.	Better thermal stability and higher storage modulus.

6 Applications of Banana Fiber Composites

Banana fiber composites are increasingly being used in diverse applications due to their exceptional mechanical properties and potential for sustainability. Their applications can be seen in the building and construction, automotive, sports equipment, and packaging industries. This section will discuss the current and potential applications of banana fiber composites, the advantages and limitations of using banana fiber composites in different applications, and case studies of successful applications of banana fiber composites. Banana fiber composites are increasingly used in the building and construction industry as a sustainable alternative to traditional synthetic composites. Using these composites in roofing materials, flooring materials, and wall panels has proven to be a game-changer, offering several benefits over synthetic composites. Firstly, banana fiber composites are eco-friendly and biodegradable, making them an attractive option for green construction projects. This is important, especially as the world is becoming more conscious of the impact of construction on the environment. Secondly, they have a high strength-to-weight ratio, making them ideal for roofing, flooring, and wall panel applications. This is because the composites offer a good balance of strength and durability, making them suitable for building and construction applications. However, one limitation of banana fiber composites in the building and construction industry is their limited availability, which could increase their cost. Nevertheless, despite this limitation, banana fiber composites in the building and construction industry are expected to grow as people become more environmentally conscious and demand eco-friendly building materials.

The automotive industry has embraced banana fiber composites as a key material in producing composite parts such as bumpers and body panels. These composites have a remarkable strength-to-weight ratio, making them a superior choice for automotive applications that require weight reduction. Additionally, their impact resistance and ability to withstand harsh weather conditions make them well-suited for the demands of the automotive industry. Despite the benefits, one potential drawback of using banana fiber composites in the automotive sector is their limited availability compared to traditional synthetic composites, which may drive up costs. The sports equipment industry has embraced banana fiber composites in producing sports equipment, such as golf clubs and tennis rackets. These composites offer several advantages over traditional materials, including a high strength-to-weight ratio and durability, making them ideal for applications in the sports industry where a balance of strength and weight is crucial. Additionally, using eco-friendly and sustainable materials aligns with the values of many sports enthusiasts and consumers. However, like other industries, one limitation of using banana fiber composites in sports is their limited availability, which could result in a higher cost than traditional synthetic composites. Despite this, the increasing demand for sustainable and high-performing materials may drive the development and production of banana fiber composites, making them more accessible and cost-effective.

In the packaging industry, banana fiber composites are a sustainable alternative to synthetic composites. The use of banana fiber in packaging provides several advantages, such as being eco-friendly, biodegradable, and having a high strength-to-weight ratio. These properties make it ideal for packaging products that need to be lightweight and durable. However, one of the limitations of using banana fiber composites in the packaging industry is their limited availability, which can lead to an increase in cost compared to traditional synthetic composites. Despite this, the use of banana fiber composites in the packaging industry is growing as consumers become more conscious of the impact that packaging has on the environment and demand more sustainable packaging solutions. Other industries, such as aerospace and medicine, also have the potential for using banana fiber composites due to their exceptional mechanical properties. However, limited availability may still be a hindrance in these industries. In addition to these applications, there is also potential for using banana fiber composites in the aerospace and medical industries, where high-performance composites are required. However, the limited availability and higher cost of these composites may pose a challenge in these industries.

7 Conclusion

In conclusion, this comprehensive review has highlighted banana fiber-reinforced composites' physical structure, chemical composition, and mechanical properties. The use of banana fibers as reinforcements in various matrices has shown promising results, particularly regarding the composite's mechanical and thermal properties. Banana fiber composites' current and future applications range from construction and packaging materials to biodegradable composites. However, despite the potential of banana fiber-reinforced composites as a sustainable alternative, several challenges still need to be addressed to realize their potential fully. Some of the key research gaps in this field include the following:

- Improved fiber extraction and preparation techniques to increase the fibers' yield and reduce production costs.
- Development of more efficient and cost-effective methods for processing banana fiber composites, including formulating new composite systems and optimizing the processing parameters.
- Further investigation into the compatibility of banana fibers with different types of matrices and the influence of the matrix type on the properties of the composites.
- Study banana fiber-reinforced composites' long-term durability and stability, including their resistance to environmental factors such as moisture and U.V. radiation.
- Exploration of new applications and markets for banana fiber composites, particularly in biomedical engineering and energy storage systems.

These research gaps provide ample opportunities for researchers, engineers, and manufacturers to explore the potential of banana fiber-reinforced composites as a sustainable alternative. By addressing these challenges, the future of banana fiber composites can be realized as a versatile and sustainable material.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Contribution

Nithesh Naik: Conceptualization, Writing-Reviewing **Nilakshman Sooriyaperakasam**: Conceptualization, Writing-Reviewing **Mahmood Al Abdali**: Conceptualization, Writing-Reviewing **Yash Parmar**: Conceptualization, Writing-Reviewing **Shresht Singh**: Investigation, Methodology, Data curation, Writing-Original draft preparation **Tejas Iyer**: Investigation, Methodology, Data curation, Writing-Original draft preparation **Chirag Agarwal**: Investigation, Methodology, Data curation, Writing-Original draft preparation **Jeswanthi Tirupathi**: Investigation, Methodology, Data curation, Writing-Original draft preparation

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