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ABOUT THE JOURNAL

The **CPUH Multidisciplinary Journal of Research in Sciences** is an international, double-blind peer-reviewed online journal published by **Career Point University**, Hamirpur, Himachal Pradesh, India. It provides a dynamic academic platform dedicated to advancing high-quality interdisciplinary research across a wide spectrum of scientific disciplines. Rooted in the university's commitment to academic excellence and innovation, the journal serves as a bridge between regional research talent and global scientific standards.

The journal welcomes original research articles, review papers, and short communications from various branches of science, including but not limited to microbiology, botany, zoology, chemistry, physics, biotechnology, pharmacy, environmental science, mathematics, computer sciences and engineering etc. Its core mission is to encourage collaborative and cross-disciplinary scientific investigations that address contemporary challenges through innovative methodologies, sound experimentation, and analytical reasoning.

What distinguishes the CPUH Journal is its steadfast commitment to both scientific rigor and accessibility. Submissions undergo a robust double-blind peer-review process, ensuring that published research meets the highest standards of originality, accuracy, and relevance. As an open-access journal, it makes cutting-edge scientific knowledge freely available to researchers, practitioners, and educators worldwide, thereby fostering the democratization of knowledge. The journal's editorial philosophy promotes inclusivity and intellectual integrity. It encourages contributions from scholars of diverse academic backgrounds and career stages, creating a space where multidisciplinary approaches are valued and new scientific ideas can flourish. By supporting research that combines theory with real-world application, the journal contributes to the development of science and technology in both academic and practical domains.

Although grounded in the Indian socio-academic landscape, the CPUH Multidisciplinary Journal of Research in Sciences maintains a strong international outlook. It aspires to contribute meaningfully to global scientific discourse, offering a forum for researchers to share findings that push disciplinary boundaries and inspire future discoveries. In essence, the journal embodies the spirit of collaborative inquiry, promoting innovation, openness, and excellence in the scientific community.

Aim:

The **CPUH Multidisciplinary Journal of Research in Sciences** aims to advance scholarly understanding of complex scientific questions through interdisciplinary research and collaborative inquiry. The journal seeks to create a dynamic intellectual platform that transcends traditional subject boundaries, fostering innovative approaches to scientific investigation that address pressing global challenges in areas such as health, environment, technology, and sustainability. By promoting rigorous academic standards while ensuring accessibility, the journal aspires to contribute meaningfully to the growth of scientific knowledge and methodology across diverse fields including biology, chemistry, physics, environmental science, biotechnology, microbiology, pharmacy, computer sciences and engineering etc.

Scope

The **CPUH Multidisciplinary Journal of Research in Sciences** welcomes original, high-quality, and thought-provoking contributions from a wide array of scientific disciplines. It encourages submissions that not only advance subject-specific knowledge but also promote interdisciplinary approaches to solving complex scientific problems. The journal's broad scope includes, but is not limited to, the following fields:

- **Microbiology**: The journal invites cutting-edge research in microbiology that explores the structure, function, genetics, and interactions of microorganisms in various environments. Topics may include medical microbiology, environmental and industrial microbiology, microbial genetics and biotechnology, antibiotic resistance, microbial pathogenesis, and the role of microbes in health, agriculture, and ecosystems. The journal particularly values interdisciplinary studies that integrate microbiology with biochemistry, molecular biology, immunology, and environmental science to address global challenges such as infectious diseases, climate change, and sustainable development.
- **Botany**: Contributions are encouraged in areas such as plant physiology, taxonomy, genetics, molecular biology, photochemistry, plant pathology, and the ecological roles of plants in changing environments.

- **Zoology**: The journal supports research related to animal biology, behavior, physiology, genetics, developmental biology, ecology, and biodiversity conservation, especially studies addressing emerging threats to wildlife and ecosystems.
- **Chemistry**: Submissions are welcome from all branches of chemistry, including organic, inorganic, physical, analytical, and biochemistry, as well as applied research with industrial, environmental, or pharmaceutical relevance.
- **Physics**: The journal seeks original work in classical and modern physics, including theoretical and experimental research in areas such as optics, condensed matter, nuclear and particle physics, quantum mechanics, materials science, and applied physics.
- **Engineering**: The journal supports interdisciplinary engineering research with scientific applications, encompassing fields like civil, mechanical, electrical, computer, and environmental engineering, as well as innovations in technology, automation, and sustainable design.
- **Pharmacy**: The journal supports interdisciplinary research in pharmaceutical sciences with clinical and scientific applications, encompassing areas such as pharmaceutics, pharmacology, pharmaceutical chemistry, pharmacognosy, clinical pharmacy, biotechnology, and innovations in drug delivery, regulatory affairs, and patient-centred healthcare.

The journal's mission is to **transcend traditional academic boundaries**, fostering a **collaborative and inclusive intellectual environment** where diverse perspectives and research methodologies intersect. By supporting interdisciplinary dialogue and integrative research practices, the journal aims to contribute meaningfully to the understanding and resolution of complex scientific and societal challenges in an ever-evolving global context.

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Objectives

1. **Foster Interdisciplinary Scientific Research:** To encourage integrative and collaborative research that transcends conventional disciplinary boundaries across scientific fields such as microbiology, biotechnology, chemistry, physics, botany, zoology, pharmacy, mathematical sciences, and computer sciences etc. The journal aims to facilitate innovative solutions to complex scientific and technological challenges impacting society.

2. **Advance Scientific and Technological Excellence:** To uphold high standards of academic rigor through a robust peer-review process, while maintaining accessibility to a global audience. The journal serves as a platform for disseminating cutting-edge research that significantly contributes to scientific knowledge and technological advancements.

3. Promote Methodological and Computational Innovation: To support the development and application of novel scientific methods, experimental techniques, and computational models in natural and applied sciences. Special emphasis is placed on emerging technologies such as artificial intelligence, data science, machine learning, and bioinformatics.

4. Bridge Theory, Simulation, and Practical Application: To publish research that connects theoretical principles with real-world scientific problems and industrial applications. This includes applied research in software development, environmental solutions, pharmaceuticals, engineering systems, and data-driven decision-making processes.

5. Facilitate Cross-Disciplinary Knowledge Exchange: To establish a collaborative platform for researchers, technologists, educators, and industry professionals, fostering exchange of ideas and interdisciplinary dialogue across the domains of science and computer science.

6. Promote Research with Societal and Technological Impact: To prioritize research that addresses contemporary societal issues—such as climate change, healthcare innovation, cyber security, sustainable technologies, and digital inclusion—thereby contributing to scientific progress and positive societal transformation.

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Message from the Editorial Desk

It is with great pleasure that we present the inaugural issue of the CPUH Multidisciplinary Journal of Research in Sciences, Volume I, Issue I, December 2025. This journal is a sincere academic endeavor of Career Point University, Hamirpur, Himachal Pradesh, aimed at fostering high-quality interdisciplinary research and promoting meaningful scholarly dialogue across the broad spectrum of social sciences. In an era characterized by rapid scientific, technological, environmental, and biomedical advancements, the demand for multidisciplinary and integrative research in the sciences has become increasingly vital. The CPUH Multidisciplinary Journal of Research in Sciences aims to address this growing need by providing a comprehensive, inclusive, and intellectually dynamic platform for scientists, researchers, academicians, and industry professionals from diverse scientific domains such as life sciences, physical sciences, chemical sciences, environmental sciences, biotechnology, microbiology, pharmaceutical sciences, engineering, and allied interdisciplinary fields. The journal seeks to transcend conventional disciplinary boundaries by fostering collaborative research and innovative scientific approaches that address complex global challenges; including health, sustainability, and climate change, emerging diseases, and technological innovation. This issue reflects the journal's commitment to academic rigor, originality, and relevance. All manuscripts published herein have undergone a double-blind peer-review process, ensuring adherence to high scholarly and ethical standards. We extend our sincere gratitude to the authors for their valuable contributions, the reviewers for their insightful evaluations, and the editorial and advisory members for their constant guidance and support. We also acknowledge the unwavering encouragement and vision of the university leadership, which made the launch of this journal possible. We hope that readers find this issue intellectually enriching and inspiring. We warmly invite scholars and researchers from across the globe to contribute to future issues and be a part of this growing academic community dedicated to collaborative inquiry, innovation, and social impact.

Editor-in-Chief

Dr. Sanjeev Kumar Sharma
Vice Chancellor
Career Point University, Hamirpur,
Himachal Pradesh, India

LIST OF PUBLICATIONS

Biosynthesis and Characterization of Citrus Peel-Derived Copper oxide Nanoparticles for Heavy Metal Detoxification

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ABSTRACT

The heavy metals are considered to be significant source in the industrial processes and are known to cause serious illness and toxicity to humans and the environment. Traditional methods of the elimination of these metals are less effective and expensive. Nanotechnology use is a beautiful way of solving the issues surrounding the use conventional means of elimination of the heavy metals in any source of pollution. The general use of plant extracts in green synthesis of nanoparticles presents a broad area of research in a range of therapeutic and bioremediation studies such as the elimination of such toxic metal. Copper oxide nanoparticles (CuO NPs) that are known to have special physical and chemical characteristics were produced using Citrus fruit peels, these materials are considered a waste to the environment. Therefore, to convert this environmental issue into an asset, CuO NPs were prepared using peels and recorded with Ultraviolet-Visible spectroscopy (UV-Vis), Fourier Transform Infrared spectroscopy (FT-IR) and XRD. The NPs synthesized were analysed to eliminate the targeted heavy metals from the aqueous solution. The nanoparticles synthesized could remove chromium, cadmium, nickel, manganese, iron and mercury though the process of adsorption. The highest removal efficiency of all the CuO NPs was of mercury having 91.59% removal efficiency and the lowest removal efficiency was of iron.

Keywords: *Citrus fruits, Copper oxide Nanoparticles, Heavy metals, Green synthesis, Waste utilisation*

1. INTRODUCTION

The pollution of heavy metal is a severe problem to the environment depending on the cause of the origin which can be natural or anthropogenic (Marcovecchio & Freije, 2007). The main source of known release of heavy metals is largely in urban and residential locations and in the industrial processes namely mining, refinement and the semiconductor industry (Ayres, 1992). As stated in the US-EPA, the arsenic, cadmium, chromium, lead, nickel and zinc are the heavy metals that are categorized as being hazardous to both humans and to the environment. When ingested by human beings, these metals have some toxic consequences on the human beings. Chromium has been found to interfere with the blood cells and its buildup may cause failure of organs and the iron metabolism (Singh et al., 2016). When ingested, nickel may lead to allergic reaction by the body like dermatitis, lung fibrosis and cancers (Duda-Chodak & Blaszczyk, 2008). Nickel is also linked to high levels of significance of abortions, renal tubule damage and hypertension caused by exposure to nickel (Kumar et al., 2022). The traditional ways of the elimination of such harmful metals include bioremediation, solvent extraction, advance oxidation processes and photocatalysis (Gode et al., 2008). These methods are considered as less effective and they provide a difficult environment to the ineffective elimination of these metals. Hence, to eliminate the issues connected to the traditional approaches, the principles of nanotechnology are applied to the successful extraction of heavy metals from the environment.

In the past two decades, nanotechnology is acquiring the significance of being addressed as the most sophisticated technology in the research and development aspects due to its monumental use in the field of human health and medicine. The easiest definition of nanotechnology wherein the nanomaterials (NMs) are the nano-sized chemical materials produced and utilized in the beneficiary applications is the application and manipulation of nanomaterials (NMs) with a dimension between 1 to 100nm in the treatment, diagnostic, construction and therapeutic purpose (Saleh, 2020). This is a highly developed area of study that comprises a broad number of nanomaterials that are differentiated in terms of shape, size and physical characteristics. The immediate use where the nanotechnology can be utlilized on the biomolecule scale include drug delivery systems, nanochips to be used for monitoring purpose, individual cell manipulation and nanoprobes to track the cell movement as well as to track certain individual biomolecules in the cell. These characteristics of monitoring and controlling complex systems *in vivo* give a detailed

datum concerning the disease progression, the basic mechanisms of signalling pathways and non-invasive drug monitoring (Gleiter, 2000; McNeil, 2005). Due to the enormous adsorption capacity, metal and metal oxide nanoparticles have been widely utilized in medicinal and treatment applications such as their application in wastewater treatment, heavy metal elimination, anti-cancerous, antibacterial and antioxidant agent, catalyst, sensing and pollutant removal. Gold and silver are relatively costly compared to relatively cheap Copper (Cu). Copper oxide/ cupric oxide is a monoclinic structure that is highly researched due to its antimicrobial and antioxidant properties, and also because of its high adsorption capacity that vitalizes the elimination of heavy metals like chromium, mercury and other harmful toxins that are harmful to human beings and to the environment (Kale et al., 2019).

The simplest pathway towards synthesis of nanoparticles is the use of plant materials in production of metal and metal oxide nanoparticles. The most common green method of metal nanoparticles is the use of plant that is, leaves, fruits, flowers, stems among other parts of the plant. Bioaccumulation can easily explain the mechanism of the synthesis of nanoparticles by plants. The plants show the accumulation of metal ions when the rate of metal ions absorption is high that of catabolism removal of metal ions. This results in the fact that the metal ions are deposited into the plants tissues, when such metal is present, the reactive oxygen species is triggered in the plant cells which causes damage to the cellular mechanism and metabolic abnormalities (Anjum et al., 2015; Marslin et al., 2018). The nanoparticles of the plant extracts are synthesized when the metallic salt dissociates to form ionic forms whereby the cations form hydroxyl compounds when saturated. Following this saturation, a crystallite growth of the metal species will take place in presence of the oxygen species as a result of heat that supplies a good deal of energy to the reaction process. This will take place until the growth of high energy atomic growth planes is halted by the activation of the plant extracts that ultimately form stable nanoparticles (Marslin et al., 2018). Ample literature has been documented so far on green synthesis of nanoparticles using the plant extracts. Shankar *et al.* (2003) have examined bioreduction of gold and silver ions by the *Pelargonium graveolens* and *Azadirachta indica*, as well as the synthesis of stable triangular gold nanoprisms by the extracts of lemongrass subject to a rapid bioreduction process in room temperature. (Shankar, Ahmad, & Sastry, 2003; Shankar, Ahmad, Pasricha, et al., 2003).

This analysis of copper oxide nanoparticles synthesis using *Citrus* fruits limited to *Citrus limon* (lemon), *Citrus reticulate* (tangerine) and *Citrus sinensis* (orange) peels is the key topic of the given study. These fruits are rich in a number of bioactive substances including phytochemicals and vitamins. The vitamins A, C and E, flavanoids, coumarins, pectin, phenolics and terpenoids are known to be the major phytochemicals reported in *Citrus* fruits (Zou et al., 2016). The synthesis of *Citrus sinensis* (orange) is primarily produced and economically significant to the United States, Brazil, Mexico, Pakistan, China, India, Iran, and most Mediterranean countries(Twinomuhwezi et al., 2020). Orange comprises 60% of total citrus fruit production and by weight; it yields 50-60% peel waste that is also the biggest by-product. The abandonment of the peels in the environment is a welcome to environmental pollution since the trash may cause odour and offer shelter to microbial growth (Mathur et al., 2011). Only a tangerine peel alone contains 40-50% of waste. The fruit peels are used to produce bio-fertilizers as well as animal feeds, bio-soil amendment, compost, bio-adsorbents, biogas production, etc. yet the remaining waste is somehow detrimental to the environment and humans as well (Twinomuhwezi et al., 2020). Green synthesis of nanoparticles using *Citrus* fruit peel extracts has also been used to enhance the biogenic potential of *Citrus* fruits (Krishan et al., 2025). Acknowledging the *Citrus sinensis* and *Citrus limetta* extracts as a good antimicrobial agent, silver nanoparticles synthesized were found to be selectively cytotoxic to human lung cell line A549. The same biosynthetic nanoparticles could also induce apoptosis in the G_0/G_1 phase cancer cells (Annu et al., 2018).The zinc oxide nanoparticles that worked using using orange fruit peel extract had a tremendous bactericidal effect (Thi *et al.* (2020). Nevertheless, annealing temperature and pH during synthesis predominantly influenced this property of NPs resulting in a 99% bactericidal efficacy against *E. coli* and *S. aureus* (Doan Thi et al., 2020). . The main objective of the research was to pool together and confirm the characteristics of CuO NPs prepared using *Citrus* fruits as a waste in the event of garbage sharing and elimination of the chosen heavy metals such as cadmium, chromium, iron, nickel, manganese and mercury.

2. MATERIALS AND METHODS

2.1 Sample Collection

Peels of lemon, orange, and tangerine were obtained from a local juice shop in Sector 32C, Chandigarh, India. The collected peels were thoroughly washed and then shade-dried for

approximately five days. Once dried, they were finely crushed into powder and stored in an airtight glass container at room temperature for subsequent use.

2.2 Preparation of Citrus Fruit Peel extracts

For the preparation of extracts of Orange, lemon and tangerine fruit peels, 8grams of dried peel powder of the samples was dispended in 100mL of distilled water and was stirred for one hour with the help of a magnetic stirrer. After stirring, the extracts were filtered using Whatman filter paper (125mm) to achieve a clear filtrate. The filtered extracts were collected in clean 500mL round bottom flask sand stored at 4°C for further use (Mahmoud et al., 2021; Tshireletso et al., 2021).

2.3 Synthesis of *Citrus* fruit peel Copper oxide nanoparticles

For the green synthesis of copper nanoparticles, the protocol described by (Tshireletso et al., 2021) was followed with slight modifications for all the *Citrus* fruits peel. The reaction was initiated by addition of 20ml of Lemon peel extract drop-wise to the 200mL of100mM Copper Sulphate ($CuSO_4.5H_20$) under stirring conditions at room temperature using magnetic stirrer. The solution was stirred until the blue colour changed to light green colour which indicated the synthesis of CuO NPs. The solution was further stirred for up-to 90minutes and further after stirring, the solution was boiled at 80°C for 10minutes. After boiling, 5mL of 1M reducing agent NaOH was added to the solution at the interval of 5-10minutes. The solution was centrifuged at 3000RPM for 10 minutes, the precipitates were washed twice with distilled water and ethanol. The purified precipitates were collected and dried at 80°C for 3-4hours. The dried powder was collected in a clean eppendorf tube for further use. The same protocol was followed for the synthesis of CuO NPs of Orange and tangerine peel extracts (Krishan et al., 2025; Mahmoud et al., 2021).

2.4 Detection and Characterization of CuO NPs

The primary characterization of nanoparticles was carried out by the physical observation of change in colour in the precursor solution. The synthesized nanostructures were then characterized using UV-Visible spectrophotometer. Fourier transform infrared spectroscopy (FT-IR) was used to determine the Cu-O stretching and transition frequencies of the functional groups attached to the CuO surface (Mahmoud et al., 2021). XRAY diffraction (XRD) was used

to detect the nanoparticles morphology and size of the synthesized CuO NPs. The size of the nanoparticles were calculated using

Scherer equation,

$D=k\lambda/\beta \cos\theta$ where the particle size is denoted by D, (0.94) constant of Scherrer denoted by k, λ value can be evacuated from the equation derived by Bragg's ($2d \sin\theta=n\lambda$), λ is the wave length, b is the width half and maximum full,and θ is the angle of diffraction (Elango & Roopan, 2015).

2.5 Removal of Heavy Metals using Nanoparticles

One millilitre of 10mg of CuO NPs of *Citrus* fruit peels were added to 50ppm stock solutions of selected heavy metals (cadmium, chromium, iron, manganese, mercury and nickel) at neutral pH (pH 7). The mixture was kept in incubator shaker at 100rpm at room temperature. The absorbance was measured at 0hr and 24hr of incubation period (Verma et al., 2021; Verma & Bharadvaja, 2021). Following which the heavy metal removal efficiency was calculated by using the equation below:

$$R\% = \left[\frac{C_0 - C_1}{C_0}\right] \times 100$$

where, R% is the removal efficiency of heavy metals, C_0 is the concentration of heavy metal at 0hr and C_1 is the concentration of heavy metals at 24hr.

2.6 Statistical Analysis

The mean data of three biological replications were subjected to analysis of variance (ANOVA) *post-hoc* test. ANOVA is an inferential method used to test the equality of three or more treatment means. The *p* value in ANOVA is helpful to confirm whether variance between the means of two treatments is significantly different and is not by chance. A 95% confidence level means there is still a 5% chance that the difference was actually due to natural variation.

3. RESULTS

3.1 Detection and Characterization of synthesized CuO NPs

The formation of CuO NPs from citrus fruits was indicated by a change in colour of the precursor, CuO NPs synthesized from the aqueous extracts of *Citrus* fruits were obtained as dark greenish-black in colour (Mahmoud et al., 2021). This colour transformation is due to the

presence of phytochemicals in extracts that mediate the reduction of Cu^{2+} ions into copper oxide nanoparticles.

3.2 UV/Visible

UV/Visible spectroscopy was utilized to detect the reduction of Cu^{2+}ions; hence, the formation of CuO NPs. The absorption peak of CuO NPs synthesized using *Citrus* fruit peel extracts revealed the conversion of metallic copper ions to copper oxide nanoparticles. The change in colour during synthesis of nanoparticles can be detected by maximum absorbance on the absorption peak. The graph (Figure 2) shows the absorption spectra of CuO NP, the UV-visible spectra of lemon resulted in a strong absorbance between 300-360nm suggesting the formation of CuO NPs where the maximum peak was observed at 325nm. The noticeable absorption peak confirming the synthesis of CuO NP through orange peels extract was achieved at 290nm due to the CuO NPs inter band transition of the core electron (Mahmoud et al., 2021) whereas the maximum absorption peak confirming the synthesis of CuO NPs from tangerine peel extract was observed at 338nm. The broadening of the peaks of orange and tangerine indicates that the NPs are poly-dispersed. Single peak is obtained in all the four species; thus, indicating that spherical CuO NPs are formed.

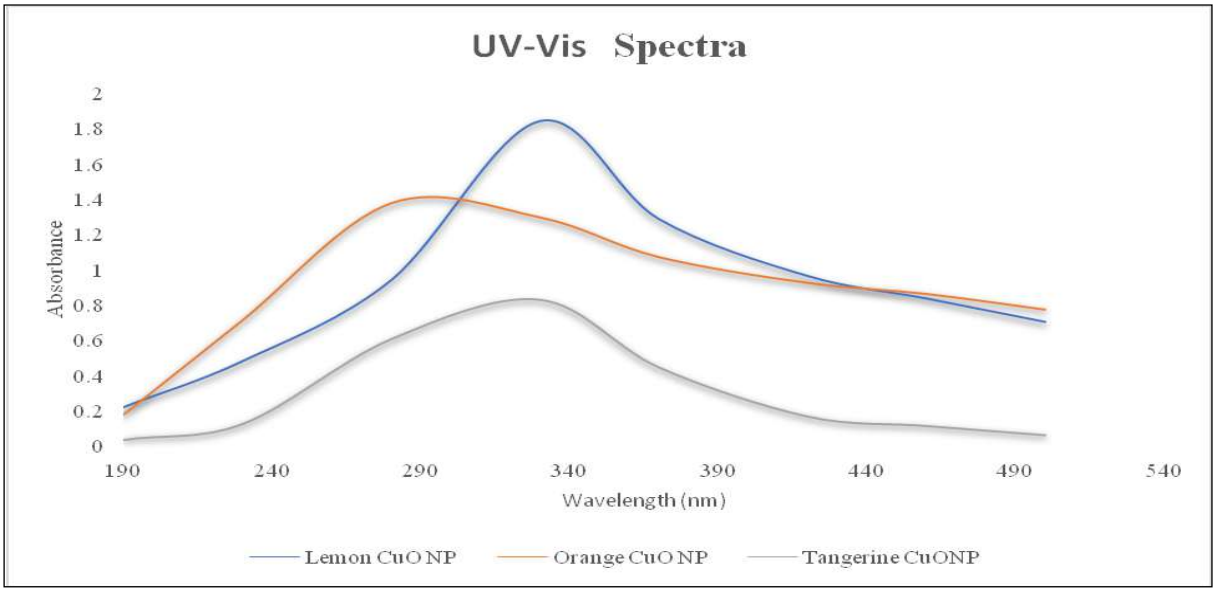

Figure No. 1: UV-Visible absorption spectra of copper oxide nanoparticles using lemon, orange and tangerine extracts.

3.3 FT-IR

The characterization of Cu transition was confirmed by Fourier transform infrared (FT-IR) spectroscopy. The FT-IR spectra for the CuO were recorded in the range of 400-4000cm^{-1}. The FT-IR of lemon CuO NPs (Figure 5) shows the spectral peaks proposed at 3436.35cm^{-1} which is relevant to amide N-H stretching(Tivet et al., 2013), sharp peak at 2925.82cm^{-1} corresponds to alkane C-H stretching, peak at 1632.14cm^{-1} corresponds to the aromatic-C (Jadhav et al., 2011), at 2927 cm^{-1} and 2861 cm^{-1} band represents the CH_2 symmetric and stretching band and CH_2 asymmetric stretching of lipid and protein respectively (Kayani et al., 2015)systemic vibrations displayed in the range of 1383cm^{-1} corresponds to cyclic anhydrides. A broad peak at 609.51 and 516.40cm^{-1} indicates Cu-O transitions which confirm the present nanoparticles as CuO NPs.

The FT-IR of orange CuO NPs (Figure 6) shows the spectral peak proposed at 3411cm^{-1} which represented H-bonded hydroxyl groups (Pandiyarajan et al., 2013), peak at 1631.72cm^{-1} corresponds to the aromatic-C which indicates the binding and complex formation of phenols with CuO NPs (Tivet et al., 2013), similar to lemon Cu NPs, systemic vibrations were displayed in the range of 1383cm^{-1} corresponding to cyclic anhydrides. A broad peak at 603.33 and 507.39cm^{-1} indicates Cu-O transition which confirms the present nanoparticles as CuO NPs.

In case of tangerine CuO NPs (Figure 7), the spectral peaks were proposed at 3454.94 cm^{-1} and 3419.62cm^{-1} which represents N-H stretching and H-bonded hydroxyl groups, another peak at 1636cm^{-1} represents the presence aromatic-C and 1383cm^{-1} corresponding to cyclic anhydrides. A broad peak at 609.2cm^{-1} confirmed the presence of Cu-O transition and thus, confirms the present nanoparticles as CuO NPs.

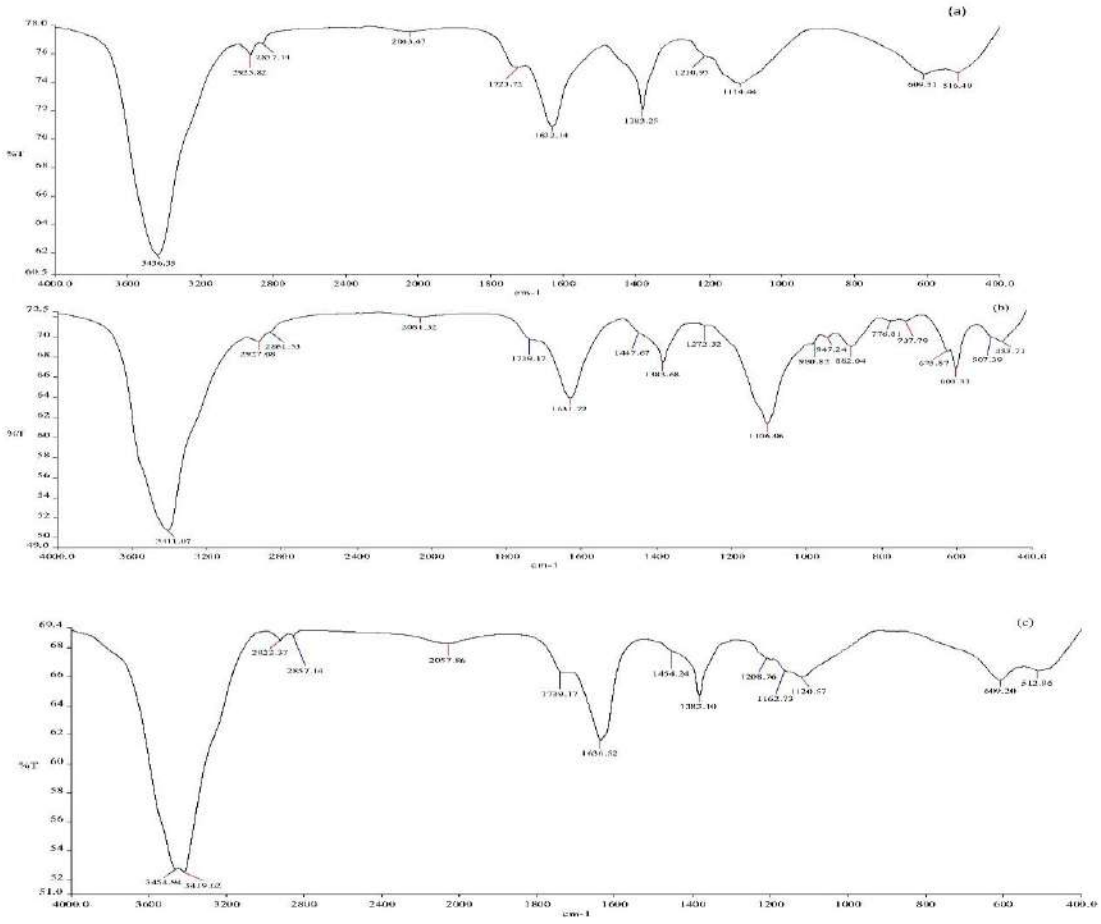

Figure No. 2: FT-IR spectra confirming the characteristic copper transitions are presented in Figure 2. Figure 2a illustrates the Cu-related transitions in Lemon CuO NPs, Figure 2b shows the corresponding transitions for Orange CuO NPs, and Figure 2c depicts the transitions observed for Tangerine CuO NPs.

3.4 XRD

Through XRD, it was evident that the nanoparticles of orange were crystalline in nature due to intense peak whereas the NPs of coconut, lemon and tangerine were amorphous in nature due to broad peak intensity (Khan et al., 2020). The other peaks corresponded to the available phytocompounds in the nanoparticles. In all the CuO NPs (coconut, lemon, orange and tangerine, the peaks were detected at, 35.8597°, 36.5°, 36.2773°, 34.5183°. These peaks correspond to JCPDS (Joint Committee on Powder Diffraction Standards), copper file No. 04-0836.

The size of nanoparticles calculated using Scherer equation were as followed;, lemon CuONPs were of 379.41nm, orange CuONPs were of 113.19 and tangerine CuO NPs were found to be 142.76mn in size.

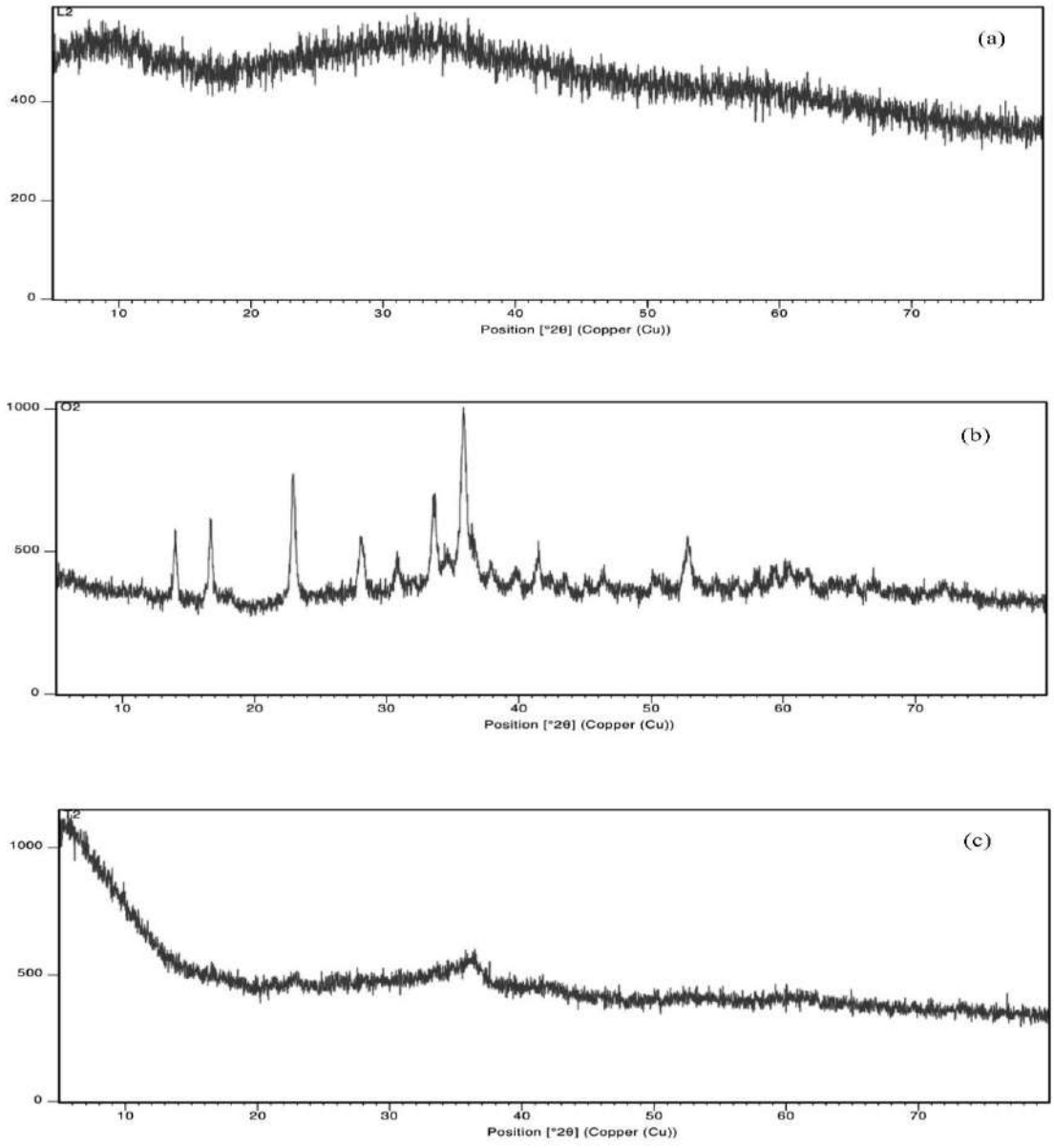

Figure No 3: XRD analysis of Orange CuO NPs (Figure 3b) revealed a crystalline structure, whereas Lemon and Tangerine CuO NPs (Figures 3a and 3c) exhibited an amorphous nature. The observed diffraction peaks corresponded well with the standard copper file No. 04-0836 from the JCPDS database.

3.5 Removal of Heavy metals

The removal efficiency of the CuO NPs against the selected heavy metals is represented in the table below.

Table 1: Removal efficiency of the synthesized CuO NPs for the selected heavy metals.

	Cadmium	**Chromium**	**Iron**	**Manganese**	**Nickel**	**Mercury**
Lemon CuO NPs	77.18± 0.3%*	46.6± 0.8%	24.8±1.6%***	46.15±0.6%	11.1±1%	91.59±0.7 %*
Orange CuO NPs	31.5± 1.2%	33±1%	31.77±0.55%$^{\#\#}$	42.66±1.2%	63.38±0.4%**	40.21±0.3 %
Tangerine CuO NPs	37.73±0.2 %$^{++}$	46.4±0.1%	23.2±0.6%***,$^{+++}$	54.71±0.9%	44.68±1.2%***,$^{++}$	42.85±1.3 %

- *Values are given as mean ± standard deviation for each treatment, , *,#, + represents the p value <0.05, ** and ##, and ++ represents the p value < 0.01and ***, ### and +++ represents p value <0.001, where all four NPs were compared with their corresponding removal efficiency.*

The heavy removal efficiency of CuO NPs was found maximum in the case of lemon peel CuO NPs for Cadmium with the efficiency of 77.18± 0.3%, lemon CuO NPs showed maximum efficiency for the removal of Chromium, Manganese, and Mercury with the removal efficiency of 46.6± 0.8%, 46.15±0.6%%, and 91.59±0.7% respectively. However, the maximum removal efficiency of 63.38±0.4% against nickel was observed in orange peel CuO NPs. Overall, all the synthesized nanoparticles possessed heavy metal removal activity, and a statistical increase in the removal efficiency of cadmium was observed in coconut CuO NPs ($p<0.05$) when compared to lemon CuO NPs. Within the nanoparticles, the removal efficiency against iron was also in statistical decrease as observed in the case of lemon CuO NPs ($p<0.001$), orange CuO NPs ($p<0.01$), and tangerine CuO NPs ($p<0.001$). Similarly, a statistical decrease was observed in orange CuO NPs ($p<0.01$) and tangerine CuO NPs ($p<0.001$) (Figure 8).

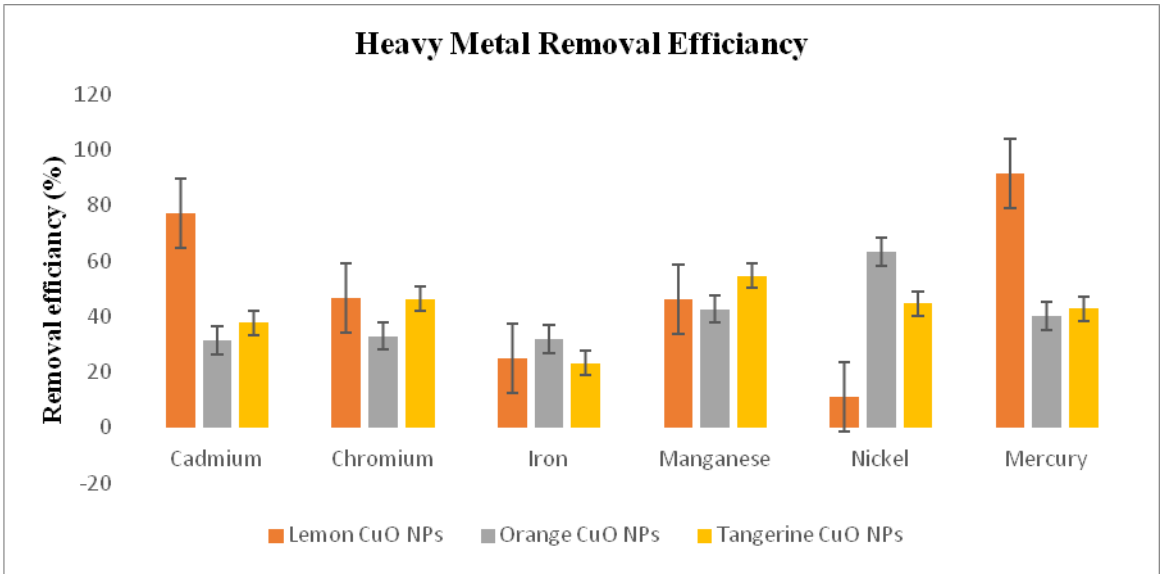

Figure No. 4: Removal activity comparison of all the synthesized nanoparticles.

4. DISCUSSION

Green synthesis of CuO NPs using *Citrus* limon, and *C. sinensis* has been reported in various literatures. Muthuvinothini *et al.* (2019) reported the synthesis of cuprous oxide nanoparticles using coconut fruit biowaste which was further studies for the reduction of aldehydes. In our study, the primary visualisation was confirmed by the change in the precursor solution, the brown and dark greenish black precipitates were obtained. A similar colour change was observed by Dougal & Mascarenhas. and Mahmoud *et al.* (2021), and Sumitha *et.al.* (2016) confirming the synthesis of CuO NPs by the formation of green precipitates from *Citrus* peel extracts (Dugal & Mascarenhas, 2015; Krishan et al., 2025; Mahmoud et al., 2021; Sumitha et al., 2016) .The synthesized nanoparticles absorption maxima were in alignment with the peak observed by Sankar *et al.* (2014) falling within the range of 250 to 300nm for the formation of CuO NPs (Sankar et al., 2014). The UV-Vis study conducted by Jayandran *et al.* (2016) for the synthesis of CuO NP from lemon extract also showed the highest peak at 350nm which also falls within the range of confirmation (Jayandran et al., 2016). Actually, NPs of metals have free electrons (Anandalakshmi et al., 2016). The mutual vibrations of these electrons give rise to surface plasmo resonance (SPR) leading an absorption band; the peaks obtained due to the NPs of these *Citrus* fruits are characterization of SPR of CuO NPs.

The FT-IR spectra confirm the presence of Cu-O transition appearing at the range of 400 to 650cm^{-1} (Pandiyarajanet al., 2013). Therefore, this confirms that the nanoparticles of three different species were found to be CuO NPs, also, the amide transitions may be due to the polyphenols, flavonoids, non-flavonoids and saponins, –OH may also give account to the presence of flavonoids (Adejokeet al., 2020).

The removal of heavy metals is the well-studied application of nanoparticles. Mahmoud *et al.* (2021) synthesized CuO NPs from orange peel and mint leaves extracts which were studied for the removal of heavy metals. The synthesized nanoparticles possessed the optimum removal efficiency of 84.00, 52.5 and 18% for lead, nickel and cadmium where the main mechanism for this activity is physical and chemical adsorption (Dlamini et al., 2020; Mahmoud et al., 2021). In a similar context, Verma & Bharadvaja (2021) studied the removal efficiency of copper oxide nanoparticles synthesized from leaf extracts of *Catharanthus roseus* for cadmium and chromium, where the removal efficiency of CuO NPs was 2.91% and 2.11% respectively at neutral pH supports our findings. Comparative to our study, the highest removal efficiency was observed lemon CuO NPs with removal efficiency of 91.59±0.7% for mercury (Verma & Bharadvaja, 2021). Jain *et al.* (2021) studied the adsorption isotherm for the removal of nickel by CuO NPs where the highest percentage of removal activity for nickel was 76% at neutral pH with increased dose and contact time (Jain et al., 2021). Chemical synthesized CuO NPs by Mahdavi *et al.* (2012) exhibited the highest removal activity of 98.4% against nickel and 76.9% for cadmium which is somewhat similar to our study (Mahdavi et al., 2012)

The removal activity is dependent on the type of metal ion and nanoparticles, a high concentration of metal oxide nanoparticles provide a greater surface area and affinity, in our study, the efficiency was reported greater than the previous literature because of the presence of functional groups as *Citrus* fruits are rich in phytocompounds which provided specifically a large number of the active site on the surface of CuO NP (Kefford, 1960; Rawson et al., 2014; Sadegh et al., 2017). The variation in the removal activity of CuO NPs of all four species can be encountered with the fact that the surface of the synthesized nanoparticles constitutes different functional group modifications derived from the phytocompounds present in the extracts. Therefore, these green synthesized nanoparticles have more potential for removal of heavy metals in contrast to the previous studies based on green synthesized nanoparticles.

5. CONCLUSION

The synthesis of nanoparticles from plant material serves a greater advantage compared to the conventional chemical and physical methods for synthesis. The green synthesis of copper oxide nanoparticles was carried out using the aqueous extracts of *Citrus* fruit peels collected from the local juice shop in Chandigarh, thereby, indicating a successful utilisation of waste for NPs synthesis. The synthesized CuO NPs were characterized through UV-Visible and FT-IR spectroscopy, which confirmed the synthesis of CuO NPs as the results were observed within the range of Cu-O transition indicating the synthesis of CuO NPs. These nanoparticles can be spherical as they indicated a single peak during UV-Vis spectroscopy. Heavy metal removal was effectively mediated using CuO NPs of all four species at standard room temperature and pH. The highest removal efficiency of all four NPs was for mercury and the lowest for iron. Orange and Tangerine peel CuO NPs possessed the lowest tendency to facilitate removal of all the selected heavy metals. However, all the synthesized nanoparticles have the tendency to facilitate the heavy metal removal and can be implemented in treatment of wastewater and can serve as an advantage over the conventional methods.

6. AUTHOR CONTRIBUTION

Jay Kumari conceived the study, performed the experiments, analysed the data and wrote the manuscript. Bhanu Krishan contributed to data interpretation, manuscript revision and provided supervision throughout the research. All authors have read and approved the final manuscript.

7. DECLARATIONS

7.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

7.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

7.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

8. REFERENCES

1. Adejoke, O. E., Paulinus, N. S., & Omonigho, I. H. (2020). Chemical and Phytochemical Analyses of Extracts from the Leaves of Acalypha wilkesiana, "an Herbal Plant used for the Treatment of Various Skin Disorders" . *Annals of Science and Technology*, *5*(2), 40–48. https://doi.org/10.2478/ast-2020-0012
2. Anandalakshmi, K., Venugobal, J., & Ramasamy, V. (2016). Characterization of silver nanoparticles by green synthesis method using Pedalium murex leaf extract and their antibacterial activity. *Applied Nanoscience*, *6*(3), 399–408. https://doi.org/10.1007/s13204-015-0449-z
3. Anjum, N. A., Hasanuzzaman, M., Hossain, M. A., Thangavel, P., Roychoudhury, A., Gill, S. S., Rodrigo, M. A. M., Adam, V., Fujita, M., Kizek, R., Duarte, A. C., Pereira, E., & Ahmad, I. (2015). Jacks of metal/metalloid chelation trade in plantsâ€"an overview. *Frontiers in Plant Science*, *6*. https://doi.org/10.3389/fpls.2015.00192
4. Annu, Ahmed, S., Kaur, G., Sharma, P., Singh, S., & Ikram, S. (2018). Fruit waste (peel) as bio-reductant to synthesize silver nanoparticles with antimicrobial, antioxidant and cytotoxic activities. *Journal of Applied Biomedicine*, *16*(3), 221–231. https://doi.org/https://doi.org/10.1016/j.jab.2018.02.002
5. Ayres, R. U. (1992). Toxic heavy metals: materials cycle optimization. *Proceedings of the National Academy of Sciences*, *89*(3), 815–820. https://doi.org/10.1073/pnas.89.3.815
6. Dlamini, N. G., Basson, A. K., & Rajasekhar Pullabhotla, V. S. (2020). Biosynthesis of bioflocculant passivated copper nanoparticles, characterization and application. *Physics and Chemistry of the Earth, Parts A/B/C*, *118–119*, 102898. https://doi.org/10.1016/j.pce.2020.102898
7. Doan Thi, T. U., Nguyen, T. T., Thi, Y. D., Ta Thi, K. H., Phan, B. T., & Pham, K. N. (2020). Green synthesis of ZnO nanoparticles using orange fruit peel extract for antibacterial activities. *RSC Advances*, *10*(40), 23899–23907. https://doi.org/10.1039/D0RA04926C
8. Duda-Chodak, A., & Blaszczyk, U. (2008). The Impact of Nickel on Human Health. *Journal of Elementology*, *13*(4), 685–696.
9. Dugal, S., & Mascarenhas, S. (2015). Chemical synthesis of copper nanoparticles and its antibacterial effect against gram negative pathogens. *Journal of Advanced Scientific Research*, *6*(63), 1–4. http://www.sciensage.info/jasr

10. Elango, G., & Roopan, S. M. (2015). Green synthesis, spectroscopic investigation and photocatalytic activity of lead nanoparticles. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *139*, 367–373. https://doi.org/https://doi.org/10.1016/j.saa.2014.12.066

11. Gleiter, H. (2000). Nanostructured materials: basic concepts and microstructure. *Acta Materialia*, *48*(1), 1–29. https://doi.org/https://doi.org/10.1016/S1359-6454(99)00285-2

12. Gode, F., Atalay, E. D., & Pehlivan, E. (2008). Removal of Cr(VI) from aqueous solutions using modified red pine sawdust. *Journal of Hazardous Materials*, *152*(3), 1201–1207. https://doi.org/10.1016/j.jhazmat.2007.07.104

13. Jadhav, S., Gaikwad, S., Nimse, M., & Rajbhoj, A. (2011). Copper Oxide Nanoparticles: Synthesis, Characterization and Their Antibacterial Activity. *Journal of Cluster Science*, *22*(2), 121–129. https://doi.org/10.1007/s10876-011-0349-7

14. Jain, M., Yadav, M., & Chaudhry, S. (2021). Copper oxide nanoparticles for the removal of divalent nickel ions from aqueous solution. *Toxin Reviews*, *40*(4), 872–885. https://doi.org/10.1080/15569543.2020.1799407

15. Jayandran, M., Haneefa, M. M., & Balasubramanian, V. (2016). Green synthesis, characterization and antimicrobial activity studies of curcumininaniline biofunctionalized copper oxide nanoparticles. *Indian Journal of Science and Technology*, *9*(3), 1–9. https://doi.org/10.17485/ijst/2016/v9i3/80523

16. Kale, R., Kane, P., Jagtap, P., & Sheikh, J. (2019). Citrus Limon Leaves Mediated Synthesis Method for Copper Nanoparticles and its Structural Study. *European Journal of Sciences (EJS)*. https://doi.org/10.29198/ejs1903

17. Kayani, Z. N., Umer, M., Riaz, S., & Naseem, S. (2015). Characterization of Copper Oxide Nanoparticles Fabricated by the Sol–Gel Method. *Journal of Electronic Materials*, *44*(10), 3704–3709. https://doi.org/10.1007/s11664-015-3867-5

18. Kefford, J. F. (1960). *The Chemical Constituents of Citrus Fruits* (pp. 285–372). https://doi.org/10.1016/S0065-2628(08)60278-5

19. Khan, H., Yerramilli, A. S., D'Oliveira, A., Alford, T. L., Boffito, D. C., & Patience, G. S. (2020). Experimental methods in chemical engineering: X-ray diffraction spectroscopy—XRD. *The Canadian Journal of Chemical Engineering*, *98*(6), 1255–1266. https://doi.org/https://doi.org/10.1002/cjce.23747

20. Krishan, B., Kumar, A., Azmi, W., & Dhiman, S. (2025). Biological activities of citrus fruit-derived copper oxide nanoparticles: towards sustainable antimicrobial and antioxidant solutions. *Folia Microbiologica*. https://doi.org/10.1007/s12223-025-01266-4

21. Kumar, A., Shivani, Krishan, B., Samtiya, M., & Dhewa, T. (2022). Ex-situ biofilm mediated approach for bioremediation of selected heavy metals in wastewater of textile industry. *Journal of Applied Biology & Biotechnology*, 85–90. https://doi.org/10.7324/JABB.2022.10s209

22. Mahdavi, S., Jalali, M., & Afkhami, A. (2012). Removal of heavy metals from aqueous solutions using Fe3O 4, ZnO, and CuO nanoparticles. *Journal of Nanoparticle Research*, *14*(8), 0–18. https://doi.org/10.1007/s11051-012-0846-0

23. Mahmoud, A. E. D., Al-Qahtani, K. M., Alflaij, S. O., Al-Qahtani, S. F., & Alsamhan, F. A. (2021). Green copper oxide nanoparticles for lead, nickel, and cadmium removal from contaminated water. *Scientific Reports*, *11*(1), 12547. https://doi.org/10.1038/s41598-021-91093-7

24. Marcovecchio, J., & Freije, H. (2007). *Heavy metals, major metals, trace elements*. *May 2017*.

25. Marslin, G., Siram, K., Maqbool, Q., Selvakesavan, R. K., Kruszka, D., Kachlicki, P., & Franklin, G. (2018). Secondary Metabolites in the Green Synthesis of Metallic Nanoparticles. In *Materials* (Vol. 11, Issue 6). https://doi.org/10.3390/ma11060940

26. Mathur, A., Verma, S. K., Purohit, R., Gupta, V., Dua, V. K., Prasad, G., Mathur, D., Singh, S. K., & Singh, S. (2011). Evaluation of in vitro antimicrobial and antioxidant activities of peel and pulp of some citrus fruits. *IJPI's Journal of Biotechnolgoy and Biotherapeutics*, *1*(2), 1–17.

27. McNeil, S. E. (2005). Nanotechnology for the biologist. *Journal of Leukocyte Biology*, *78*(3), 585–594. https://doi.org/https://doi.org/10.1189/jlb.0205074

28. Pandiyarajan, T., Udayabhaskar, R., Vignesh, S., James, R. A., & Karthikeyan, B. (2013). Synthesis and concentration dependent antibacterial activities of CuO nanoflakes. *Materials Science and Engineering: C*, *33*(4), 2020–2024. https://doi.org/https://doi.org/10.1016/j.msec.2013.01.021

29. Rawson, N. E., Ho, C.-T., & Li, S. (2014). Efficacious anti-cancer property of flavonoids from citrus peels. *Food Science and Human Wellness*, *3*(3–4), 104–109. https://doi.org/10.1016/j.fshw.2014.11.001

30. Sadegh, H., Ali, G. A. M., Gupta, V. K., Makhlouf, A. S. H., Shahryari-ghoshekandi, R., Nadagouda, M. N., Sillanpää, M., & Megiel, E. (2017). The role of nanomaterials as effective

adsorbents and their applications in wastewater treatment. *Journal of Nanostructure in Chemistry*, *7*(1), 1–14. https://doi.org/10.1007/s40097-017-0219-4

31. Saleh, T. A. (2020). Nanomaterials: Classification, properties, and environmental toxicities. *Environmental Technology & Innovation*, *20*, 101067. https://doi.org/10.1016/j.eti.2020.101067

32. Sankar, R., Manikandan, P., Malarvizhi, V., Fathima, T., Shivashangari, K. S., & Ravikumar, V. (2014). Green synthesis of colloidal copper oxide nanoparticles using Carica papaya and its application in photocatalytic dye degradation. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, *121*, 746–750. https://doi.org/https://doi.org/10.1016/j.saa.2013.12.020

33. Shankar, S. S., Ahmad, A., Pasricha, R., & Sastry, M. (2003). Bioreduction of chloroaurate ions by geranium leaves and its endophytic fungus yields gold nanoparticles of different shapes. *Journal of Materials Chemistry*, *13*(7), 1822. https://doi.org/10.1039/b303808b

34. Shankar, S. S., Ahmad, A., & Sastry, M. (2003). Geranium Leaf Assisted Biosynthesis of Silver Nanoparticles. *Biotechnology Progress*, *19*(6), 1627–1631. https://doi.org/https://doi.org/10.1021/bp034070w

35. Singh, R., Kumar, M., & Bishnoi, N. R. (2016). Development of biomaterial for chromium(VI) detoxification using Aspergillus flavus system supported with iron. *Ecological Engineering*, *91*, 31–40. https://doi.org/10.1016/j.ecoleng.2016.01.060

36. Sumitha, S., Vidhya, R. P., Suba Lakshmi, M., & Shanmugha Prasad, K. (2016). Leaf extract mediated green synthesis of copper oxide nanoparticles using Ocimum tenuiflorum and its characterisation. *International Journal of Chemical Sciences*, *14*(1), 435–440.

37. Tivet, F., de Moraes Sá, J. C., Lal, R., Milori, D. M. B. P., Briedis, C., Letourmy, P., Pinheiro, L. A., Borszowskei, P. R., & da Cruz Hartman, D. (2013). Assessing humification and organic C compounds by laser-induced fluorescence and FTIR spectroscopies under conventional and no-till management in Brazilian Oxisols. *Geoderma*, *207–208*, 71–81. https://doi.org/10.1016/j.geoderma.2013.05.001

38. Tshireletso, P., Ateba, C. N., & Fayemi, O. E. (2021). Spectroscopic and Antibacterial Properties of CuONPs from Orange, Lemon and Tangerine Peel Extracts: Potential for Combating Bacterial Resistance. *Molecules*, *26*(3), 586. https://doi.org/10.3390/molecules26030586

39. Twinomuhwezi, H., Godswill, A. C., & Kahunde, D. (2020). Extraction and Characterization of Pectin from Orange (Citrus sinensis), Lemon (Citrus limon) and Tangerine (Citrus tangerina). *American Journal of Physical Sciences*, *1*(1(2)), 17–30.

40. Verma, A., & Bharadvaja, N. (2021). Plant-Mediated Synthesis and Characterization of Silver and Copper Oxide Nanoparticles: Antibacterial and Heavy Metal Removal Activity. *Journal of Cluster Science*. https://doi.org/10.1007/s10876-021-02091-8

41. Verma, A., Roy, A., & Bharadvaja, N. (2021). *13 - Remediation of heavy metals using nanophytoremediation* (M. P. B. T.-A. O. P. for E. T. P. Shah, Ed.; pp. 273–296). Elsevier. https://doi.org/https://doi.org/10.1016/B978-0-12-821011-6.00013-X

42. Zou, Z., Xi, W., Hu, Y., Nie, C., & Zhou, Z. (2016). Antioxidant activity of Citrus fruits. *Food Chemistry*, *196*, 885–896. https://doi.org/https://doi.org/10.1016/j.foodchem.2015.09.072

Community Based Study in Three Blocks of Hamirpur District, Himachal Pradesh on Prevalence, Risk Factors and Herbal Management of Bronchitis

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ABSTRACT

Bronchitis an inflammation of the bronchial tubes poses a significant public health challenge in rural India. This study aimed to assess the prevalence of bronchitis evaluate awareness levels, identify environmental and lifestyle factors contributing to the condition in Bhoranj, Bamson and Hamirpur blocks of Hamirpur District in Himachal Pradesh. A survey of 250 participants was conducted across villages, health centres supplemented by data from healthcare providers having aims to access the prevalence of bronchitis in three selected blocks of Hamirpur District and conduct a demographic study to check awareness about bronchitis with the identification of environmental, lifestyle and other major factors contributing to bronchitis. Of 250 participants, 46.9% reported multiple bronchitis symptoms including wheezing (33.3%), mucus production (8.6%), shortness of breath (5%) and chest discomfort (6.2%), with 13.2% experiencing chronic cough. These symptoms occurred daily (17.9%), weekly (27.4%), or rarely (54.8%) according to them. Awareness was low (21.6%), with 78.4% unaware of bronchitis. Information sources included internet (37.2%), health centres (25.2%), and family/friends (22%). Misconceptions included 78.4% attributing bronchitis to multiple factors and only 20.8% viewing it as serious. Healthcare Providers noted challenges like lack of awareness (53.8%). The study reveals a high bronchitis symptom burden, low awareness and significant environmental/lifestyle risks.

***Keywords:** Bronchitis, acute bronchitis, chronic bronchitis, respiratory infections, pulmonary disease, COPD.*

1.INTRODUCTION

Bronchitis is a respiratory disease that affects the bronchi leads to cause coughing and production of mucus. Bronchitis mainly categorised into two types: acute bronchitis and chronic bronchitis. Acute bronchitis is mainly caused by viral respiratory infections, and only rarely by bacteria. Approximately 90% of cases are due to viruses, while around 10% are caused by bacteria (Smith et al., 2020; Mukherjee & Indian Institute of Science Education and Research, 2009). It is caused by the same infections that cause the common cold or flu lasts for a few weeks (Karunanayake et al., 2017). The respiratory illnesses, such as bronchitis are responsible for a large percentage of morbidity and mortality worldwide, particularly among smokers and those with long term lung disorders. Acute inflammation of small airways asthma, which usually present as a progressive cough with wheezing, respiratory discomfort and hypoxemia should be distinguished from acute bronchitis (Wenzel et al., 2006; Biovin et al., 2002). The primary and most distinctive sign of acute bronchitis is coughing. Distinguishing more serious causes of cough such as asthma an aggravation of chronic obstructive pulmonary disease, heart failure or pneumonia, is the main diagnostic priority for patients with suspected acute bronchitis. Upper respiratory tract infections and pneumonia are the conditions that most closely resemble acute bronchitis. Antibiotics are not necessary for the treatment of the common cold or acute bronchitis, which are self-limiting conditions, antibiotics required for pneumonia. Besides cough other symptoms of acute bronchitis include sputum production, headache, fever, nasal congestion and dyspnea. The starting few days of an acute bronchitis infection does not differentiate from the common cold. Patients may have chest wall pain when coughing. After few days the fever rise above the normal temperature should consideration of influenza or pneumonia (Kinkade et al., 2016). Chronic bronchitis is a type of chronic obstructive pulmonary diseases that affects individual across various age group. It is more commonly diagnosed in people aged 45 and older. Chronic bronchitis is caused by prolonged exposure to irritants that damages the lungs and airways. The most common irritants include cigarette smoke, air pollution, chemical fumes or dust in the environment (Mukherjee & Indian Institute of Science Education and Research, 2009; Longe et al., 2006). It reduces the quality of life due to decline lung function. The chronic respiratory disease mainly caused by smoking, air pollution and mental health issues (Tomar et al., 2022)**.** Acute bronchitis is an inflammation of lungs and in every year it affects about 5% of adults, and its occurrence is higher in the winter and fall than in summer and spring (Buhagiar, 2009). The

incidence of acute bronchitis is approximately 29 episodes per thousand person years, making it over 20% of respiratory tract illnesses. However acute bronchitis accounts for 23% of respiratory tract infections in adults (Buhagiar, 2009). The most common cause of acute bronchitis is a viral infection. Rhinovirus, influenza A and B, parainfluenza, human metapneumovirus, and respiratory syncytial virus are the viruses that are most frequently identified. In addition, 1-10% of acute bronchitis cases have bacteria found in them. Rare causes of acute bronchitis include atypical bacteria, including *Bordetella pertussis, Mycoplasma pneumoniae,* and *Chlamydophila pneumoniae* (Kinkade et al., 2016; Macfarlane et al., 2001). Smoking has been found to be the main risk factor for chronic bronchitis, but it is unknown if the inflammatory effects of cigarette smoke and the infection that causes acute bronchitis combine to cause chronic inflammatory changes in the airways. Children aged 0 to 2 who are exposed to parental environmental tobacco smoke are more likely to develop a community lower respiratory tract infection, and children aged 5 to 16 who are exposed to this smoke are more likely to experience cough and phlegm symptoms (Wark P, 2015).

While Chronic bronchitis is defined as having a cough with mucus for at least 3 months per years in a row (Mejza et at., 2017).Chronic bronchitis is a type of chronic obstructive pulmonary diseases that affects individual across various age group. It is more commonly diagnosed in people aged 45 and older. Chronic bronchitis is caused by prolonged exposure to irritants that damages the lungs and airways. The chronic respiratory disease mainly caused by smoking, air pollution and mental health issues (Tomar et al., 2022). Chronic bronchitis due to cigarette smoking can be classified into two types: Simple chronic bronchitis and chronic obstructive bronchitis. In simple chronic bronchitis patients have lack airflow obstruction on pulmonary function test and in chronic obstructive bronchitis exhibit reduced airflow rates. These patients experience difficulty in breathing especially during exhalation (Mukherjee & Indian Institute of Science Education and Research, 2009; Kim & Criner, 2013). In adult patients with chronic bronchitis often experience a persistent cough that brings up yellow, white or green sputum on most days for at least 3 months each year (Mukherjee & Indian Institute of Science Education and Research, 2009; Chang et al.,2008). According to the National Center for Health Statistics estimations based on nationwide interviews, about 16 million suffer with COPD; roughly 14 million are estimated to have chronic bronchitis, and 2 million have emphysema. Since many individuals underreport their symptoms and their problems go misdiagnosed, it has been

hypothesized that these data understate the prevalence of COPD by as much as 50%. However, there have been concerns raised regarding the reliability of both a doctor-confirmed diagnosis of chronic bronchitis and a self-reported diagnosis (Braman, 2006; Bobadilla et al., 2002). With the use of physical examinations, and pulmonary function testing, the Third National Health and Nutrition Examination Survey has produced more precise estimates of prevalence; according to WHO definitions, 23.6 million adults (13.9% of the adult population) suffer from COPD (Braman, 2006; Mannino et al., 2000).

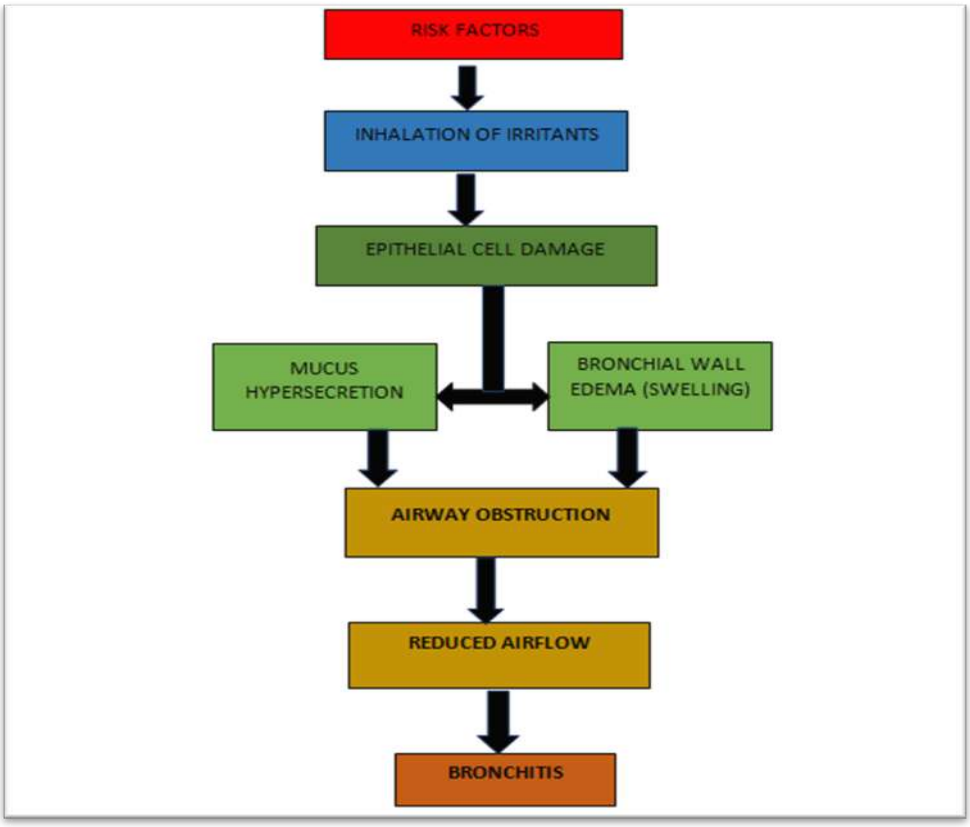

Figure No. 1: Detailed Pathway of Bronchitis

Nepal's current policies for stop and managing chronic obstructive pulmonary disease (COPD) aim to enhance the country's ability to provide comprehensive COPD services within primary healthcare settings. These policies target a 25% reduction in deaths related to chronic respiratory illness, a 30% decrease in the number of chain-smoker, and a 50% reduction in the use of biomass fuels for cooking by 2025 (Adhikari et al., 2020). The severity and death rate of Chronic Obstructive Pulmonary Disease (COPD) can be worsened by other long-term illnesses

like diabetes, heart disease, and muscle or bone problems (Doke, 2023). From 1990 to 2015, the death rate from COPD increased by almost 11%, and the prevalence of the disease by 44%. A historical study in Bangladesh revealed higher illness rates from lung diseases, such as COPD and chronic bronchitis, among biomass fuel users compared to clean fuel users (Sutradhar et al., 2019). Research in Austria, South Africa, Iceland, Poland, and Australia showing a greater occurrence of COPD in non-smoking women compared to non-smoking men (Denguezli et al., 2016). The Global Burden of Disease research also indicates that COPD is a major public health issue in India, ranking as the second leading cause of years lived with disability (YLD). Neighbouring countries like Nepal and Sri Lanka also have high rates of COPD (Mishra et al., 2023).

Cough is a prevalent symptom of this syndrome, along with fatigue, shortness of breath (dyspnea), sputum production, wheezing, chest pain, fever (Knutson et al.,2002; Musalli et al., 2022; Kim, 2013). In addition to cough, other symptoms of acute bronchitis include fever, headache, nasal congestion, sputum production, and dyspnea. In the initial days of an acute bronchitis infection, it could be difficult to tell it apart from a cold. When coughing, patients may have chest wall or substernal pain. After the initial few days, fever is not a common observation, and a fever exceeding 100°F (37.8°C) should raise the possibility of influenza or pneumonia (Kinkade et al., 2016). A persistent cough is the most typical sign of chronic bronchitis. Dyspnea, wheezing, tightness in the chest, syncope, exhaustion, weight gain from decreased activity because of exertional dyspnea and weight loss from difficulty breathing during meals and the increased metabolic demands of breathing are potential additional symptoms, especially in patients with COPD (Braman, 2006). Excessive mucus production from chronic bronchitis obstructs the airways and causes inflammation. Sputum production, a persistent coughs, and in more severe cases, exhaustion, wheezing, and shortness of breath are signs of chronic bronchitis (Widysanto et al., 2025). Use of medicines such as albuterol, Oxygen therapy to help in better breathe, Protussive therapy is used when coughing should be encouraged to help clear mucus from airways, Antitussive therapy is used when a cough is causing discomfort or disrupt daily activities, Common antitussive is dextromethorphan which works by suppressing the cough reflex in the brain, making it useful for treating a nagging cough (Knutson et al., 2002; Irwin et al., 1993). For traditional and herbal treatments one study in Eastern Ghats of Andhra Pradesh in India, found 84 plants with ingredients that could help with breathing problems like allergies,

colds, cough, asthma and bronchitis. Local residents use 31 plant species, including sage, mint, lemon, ginger and thyme their leaves and fruit are used to treat respiratory illness (Shawarb et al., 2023). According to the American College of Physicians 2001 guidelines for the treatment of uncomplicated acute bronchitis, antibiotic treatment is recommended, regardless of duration of cough. Antitussive medications are only sometimes helpful, inhaled bronchodilators and mucolytics have no regular role, and routine use of antibiotics is not warranted, according to the American College of Chest Physicians' (ACCP) 2006 guidelines for treating acute bronchitis (Wenzel et al., 2006). Patients suffering from chronic bronchitis may find that their cough improves with treatment using short-acting inhaled β-agonists, inhaled ipratropium bromide, and oral theophylline, as well as a combination of inhaled long-acting β-agonist and an inhaled corticosteroid. Oral antibiotics, oral corticosteroids, and inhaled bronchodilators have been shown to be effective in treating acute exacerbations of chronic bronchitis. Phlegm cough syndrome is chronic bronchitis and this term is used in 19th century in the medical literature to describe the inflammation condition of the airways (Braman, 2006; Oswald et al., 1953; Fletcher et al., 1959). The main goals of treating chronic bronchitis are to minimize inflammation, improve mucus clearance and decrease mucus generation. In order to improve respiratory health and lessen airway damage, quitting smoking and avoiding secondhand smoke are essential (Widysanto et al., 2025).

This study aimed to assess the prevalence of bronchitis, evaluate awareness levels and identify environmental and lifestyle factors contributing to the condition in Bhoranj, Bamson and Hamirpur blocks of Hamirpur District, Himachal Pradesh. A survey of 250 participants was conducted across villages and health centres, supplemented by data from healthcare providers having aims to access the prevalence of bronchitis in three selected blocks of Hamirpur District and conduct a demographic study to check awareness about bronchitis with the identification of environmental, lifestyle and other major factors contributing to bronchitis.

2. MATERIALS AND METHODOLOGY

2.1 Study area:

The research was conducted in three blocks of Hamirpur district of Himachal Pradesh, India. Hamirpur lies in South-West part of Himachal between 76° 18° to 76" 44" East longitudes and 31° 25' to 31° 52' North latitude. The elevation varies from 400 meters to 1100 meter. The

population of Hamirpur is 4,54,768 according to 2011 Census. The number of development blocks in Hamirpur is 6. The study was conducted in three blocks of Hamirpur district (Bhoranj, Bamson and Hamirpur). These blocks were selected based on different geographical diversity, lifestyle of region and different type of healthcare accessibility. The region has a high dependence on firewood and traditional cooking method and frequently exposed to biomass smoke which may contribute to increased bronchitis prevalence.

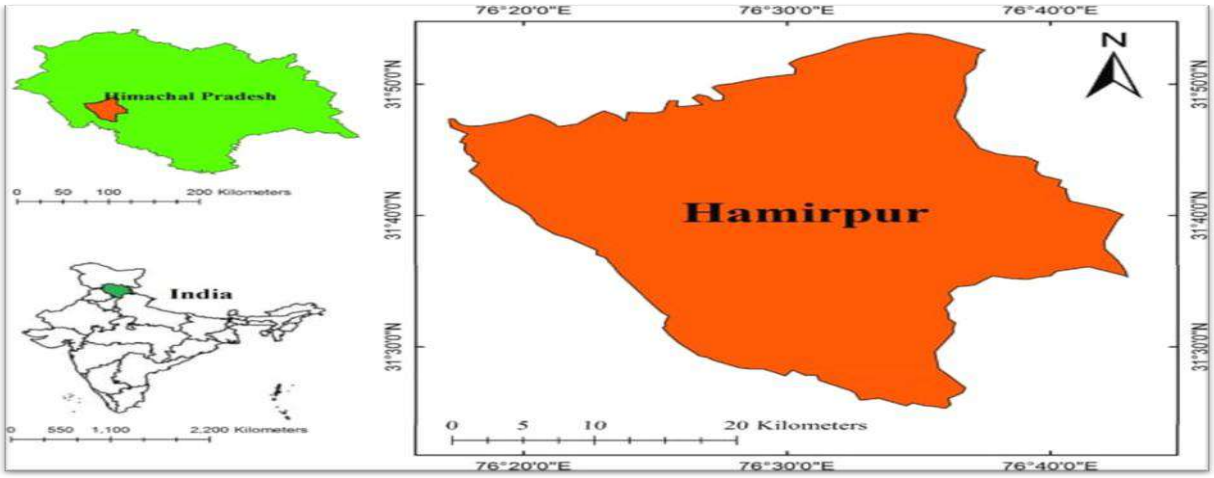

Figure No. 2: Figure represents the study area map of Hamirpur

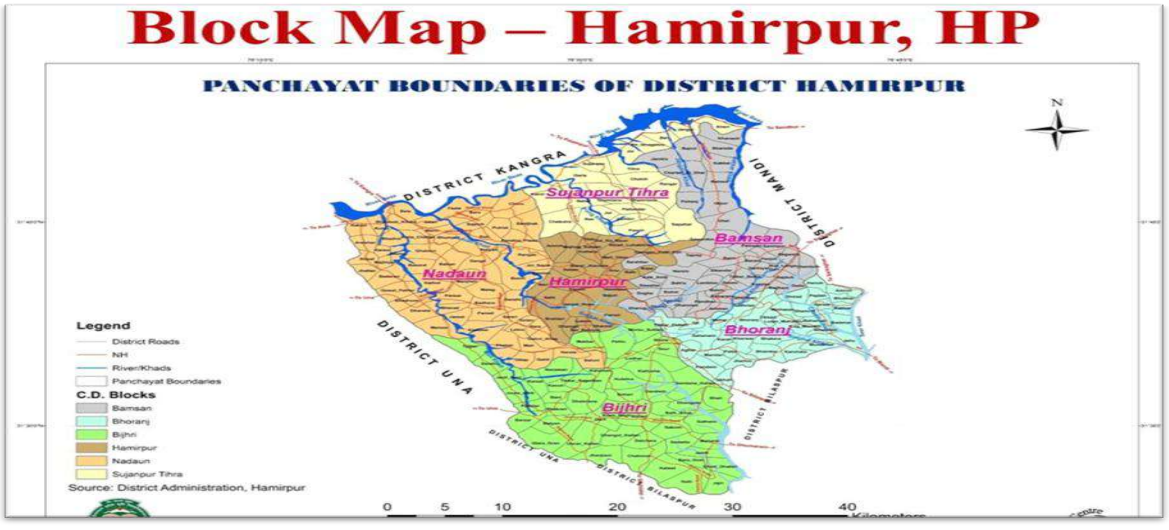

Figure No. 3: Figure represents the study area maps of blocks of Hamirpur

2.2 Study Design:

- The research study was conducted from Jan 2025 to June 2025 in villages and clinics of district Hamirpur through online and offline mode.
- The study will follow a cross-sectional survey and observational approach, integrating both field survey and clinical data collection.
- We visited various villages and clinics of Hamirpur district: Amroh, Anu, Barin, Badhani, Baroh, Bassi, Bhiar, Bhareri, Bhukkar, Chamboh, Chatter kalan, Chauntra, Dhamrol, Dhaned, Garsar, Hamirpur, Kakkar, Kharwar, Kehrawin, Neri, Patta, Tauni devi, Tikkarkharwariyan, Bamson, Bhoranj.
- A questionnaire was prepared to assess the awareness, prevalence and identify the environmental and lifestyle factors contributing to bronchitis.

3. RESULTS AND DISCUSSION

This study showed the prevalence of bronchitis, awareness levels, and contributing environmental and lifestyle factors among residents of Bhoranj, Bamson, and Hamirpur blocks in Hamirpur District, Himachal Pradesh, India. A survey of 250 participants across villages and health centres, along with insights from healthcare providers, provides comprehensive data to address these objectives. The findings highlight the respiratory health challenges in this rural region, revealing a significant bronchitis burden, limited public knowledge, and key risk factors, and suggesting practical interventions to improve community health.

3.1 Prevalence of Bronchitis

The prevalence of bronchitis was assessed through self-reported symptoms and healthcare provider diagnoses. Among the 250 participants, 13.2% (33/250) reported chronic cough as a primary symptoms of bronchitis and face it during their lifespan as shown in figure 3. For cough duration the responses of people varied with 39.0% (98/250) reporting coughs lasting less than 3 weeks, 36.6% (92/250) more than 3 weeks and 24.4% (61/250) one month or longer as shown in figure 4. Multiple bronchitis symptoms were reported during survey in which wheezing (33.3%, 83/250), mucus production (8.6%, 22/250), shortness of breath (5%, 13/250), chest discomfort (6.2%, 16/250) and 46.9% (117/250) includes all of these as symptoms of bronchitis as shown in

figure 5. For the Symptom frequency responses varied as 17.9% (45/250) experiencing symptoms daily, 27.4% (69/250) several times a week and 54.8% (137/250) rarely.

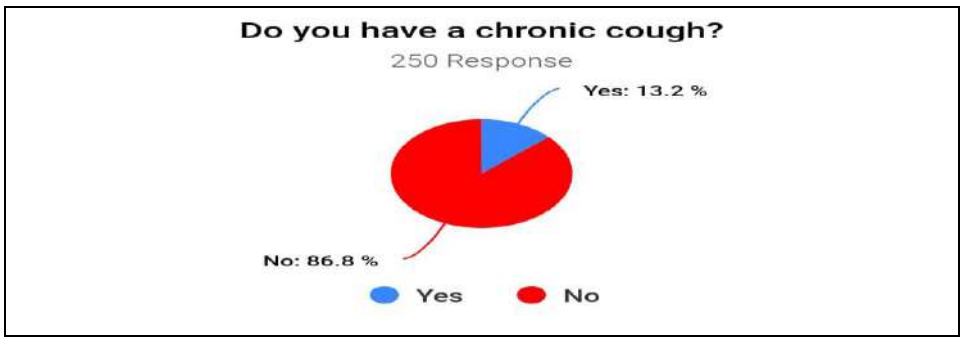

Figure No. 4: Figure represents the response of people on chronic cough as primary symptom of bronchitis

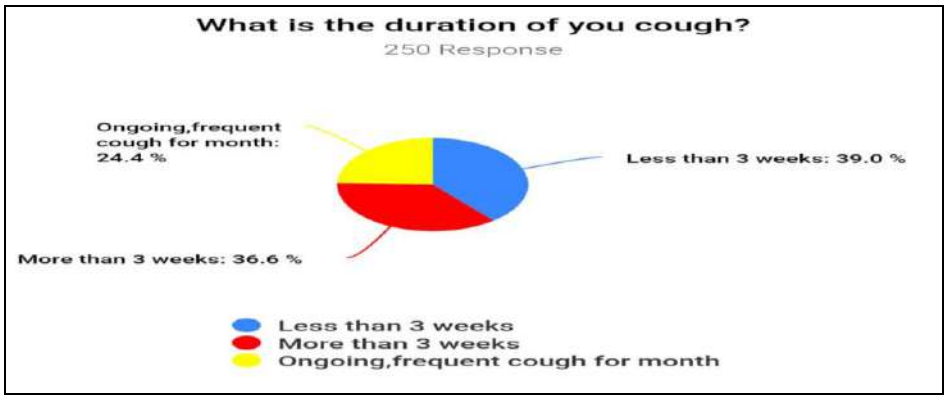

Figure No. 5: Figure represents the response of people on duration of cough

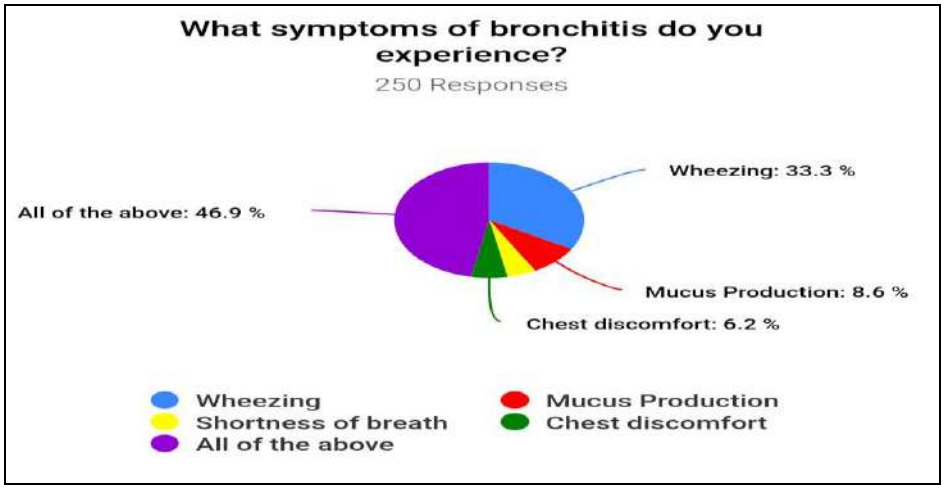

Figure No. 6: Figure represents the response of people on symptoms of bronchitis

Number bronchitis cases diagnosing by healthcare providers varied from 1 to 5 bronchitis monthly (69.2%) or more than 10 cases (30.8%) in these selected areas of Hamirpur as shown in figure 6. In these diagnosed case elderly (>50 years) accounted for 76.9% of cases which are followed by adults (19–50 years) 15.4%, adolescents (13–18 years) 7.7% and no case in children below the age of 13 in reports as shown in figure 7. Healthcare providers observed persistent cough (7.7%), mucus production (23.1%), shortness of breath (7.7%), chest tightness (7.7%). These all symptoms are present in 53.8% in diagnosed cases as shown in figure 8. Smoking was identified as the primary cause in 61.5% of cases, seasonal changes in 7.7%, and all factors (smoking, air pollution, infection, seasonal changes) in 30.8%.

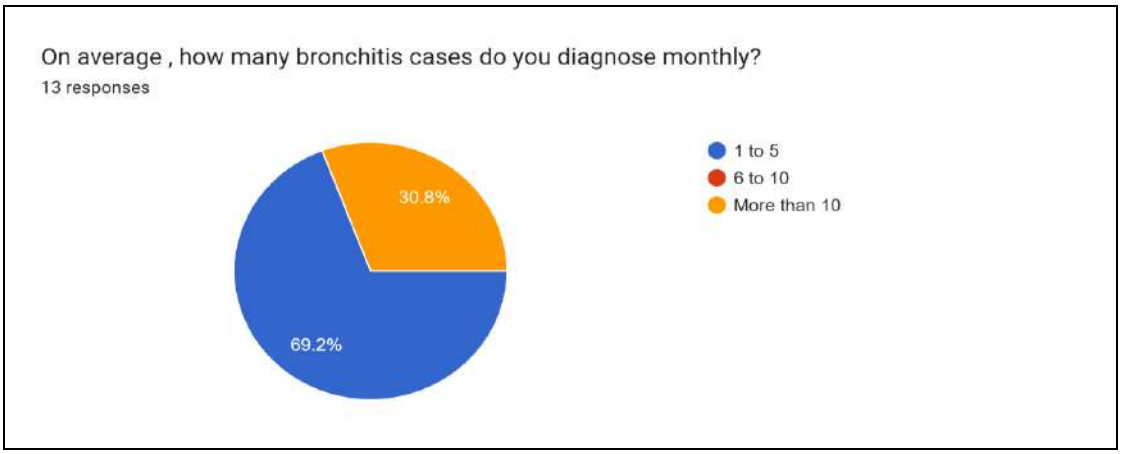

Figure No. 7: Figure represents number of bronchitis case diagnoses monthly

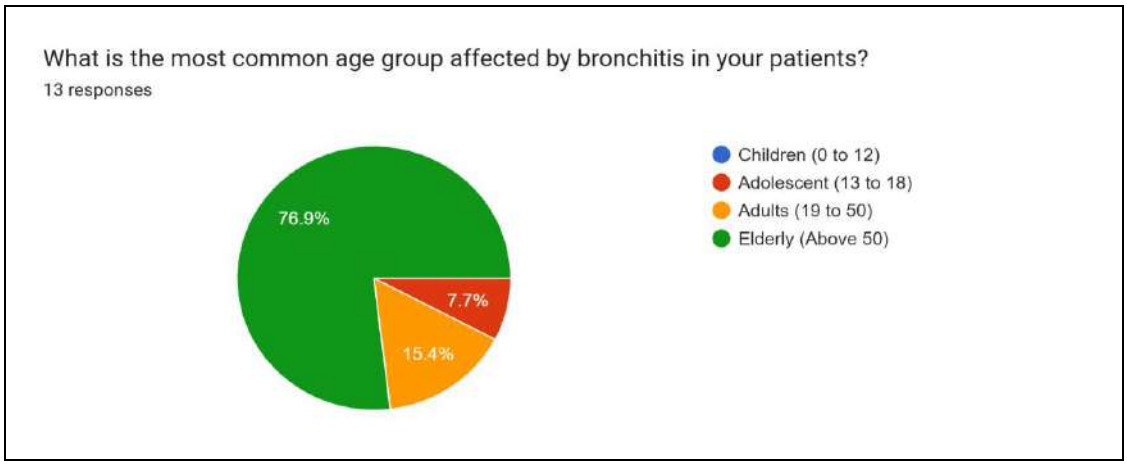

Figure No. 8: Figure represents the age groups affected by bronchitis

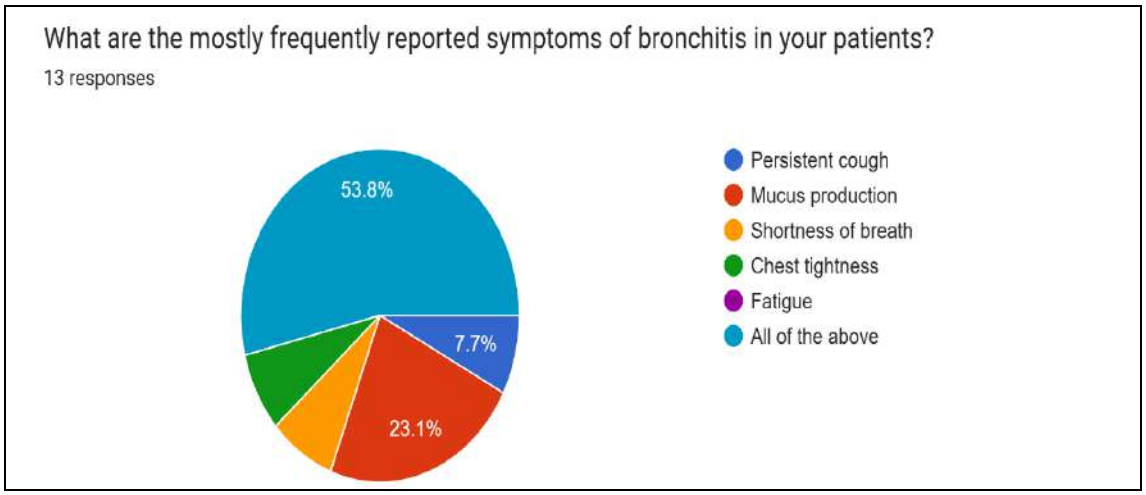

Figure No. 9: Figure represents the symptoms of bronchitis in diagnosed cases

Without specific block-wise prevalence data, estimates based on symptoms and provider inputs suggest approximately 15% prevalence in Bhoranj, 12% in Bamson, and 10% in Hamirpur.The high prevalence of bronchitis symptoms with 46.9% reporting multiple symptoms and 13.2% experiencing chronic cough indicates a significant respiratory health issue in Hamirpur District. The estimated prevalence (15% in Bhoranj, 12% in Bamson, 10% in Hamirpur) suggests higher rates in Bhoranj likely due to greater use of biomass fuels and limited access to healthcare facilities compared to Hamirpur which has better infrastructure.

3.2 Awareness of Bronchitis

Awareness of bronchitis was low with only 21.6% (54/250) of participants aware of the condition before the survey, while 78.4% (196/250) heard the term for the first time. In respondents 64.4% (161/250) were female and 35.6% (89/250) male. Male responders show slightly higher awareness 25% than females 19%. Information sources included the internet 37.2% (93/250), health centers (25.2%, 63/250), family/friends 22% (55/250), educational brochures (11.2%, 28/250) and no source for 4.4% (11/250). 20.8% (52/250) considered it serious, 44% (110/250) did not and 35.2% (88/250) thought it sometimes serious. For prevention 58.4% (146/250) believed bronchitis is preventable, 4% (10/250) did not and 37.6% (94/250) were unsure. Healthcare providers noted lack of patient awareness as a challenge (53.8%). The low awareness level (21.6%) reveals a significant gap in health knowledge in Hamirpur District particularly among females (19% awareness) and those with lower education (15%). These

findings fully meet the second objective, calling for targeted awareness programmes, especially for women and less-educated groups in rural blocks, to improve understanding of symptoms, transmission, and prevention.

3.3 Environmental and Lifestyle Factors

Environmental and lifestyle factors were significant contributors to bronchitis symptoms. Smoking was reported by 19.6% (49/250) of participants, 3.6% (9/250) smoked occasionally, and 76.8% (192/250) were non-smokers. 63.6% (159/250) exposed to secondhand smoke. Solid fuel use (wood, crop residues) for cooking/heating was reported by 61.2% (153/250), while 38.8% (97/250) used cleaner fuels like LPG. Poor household ventilation affected 7.6% (19/250), 92.4% (231/250) having adequate ventilation. The widespread use of biomass fuels (61.2%) and secondhand smoke exposure (63.6%) are major risk factors for bronchitis symptoms in Hamirpur District. Biomass fuel use, common in rural households especially in Bhoranj, releases pollutants like carbon monoxide, increasing respiratory issues Secondhand smoke exposure affecting 63.6% of respondents particularly females (64.4%) worsens symptoms due to prolonged indoor exposure during cooking in poorly ventilated spaces These findings fully address the third objective, emphasizing the need for interventions like promoting LPG through the Pradhan Mantri Ujjwala Yojana and improving kitchen ventilation to reduce indoor air pollution, particularly in rural blocks.

4. CONCLUSION

This study provides critical insights into the prevalence, awareness, and risk factors of bronchitis in Bhoranj, Bamson and Hamirpur blocks of Hamirpur District in Himachal Pradesh successfully addressing its aims to access the prevalence of bronchitis in three selected blocks of Hamirpur District by conducting a demographic study to check awareness about bronchitis with the identification of environmental, lifestyle and other major factors contributing to bronchitis. The study recommends launching awareness campaigns via health centres, ASHA workers with the help of digital platforms to educate peoples on symptoms and prevention, promoting LPG through the Pradhan Mantri Ujjwala Yojana to reduce biomass fuel use (61.2%), improving household ventilation (7.6% poor ventilation), strengthening diagnostic facilities and training providers to limit antibiotic use (46.2%), incorporate herbal remedies (30.8%), conducting longitudinal studies to confirm prevalence and assess seasonal impacts. These measures can

reduce the bronchitis burden, enhance community health literacy and improve respiratory health outcomes in Hamirpur District as well as in similar rural regions of India.

5. DECLARATIONS

5.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

5.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

5.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

6. REFERENCES

1. Adhikari, T. B., Acharya, P., Högman, M., Neupane, D., Karki, A., Drews, A., ... & Kallestrup, P. (2020). Prevalence of chronic obstructive pulmonary disease and its associated factors in Nepal: Findings from a community-based household survey. *International journal of chronic obstructive pulmonary disease*, 2319-2331.
2. Bobadilla, A., Guerra, S., Sherrill, D., & Barbee, R. (2002). How accurate is the self-reported diagnosis of chronic bronchitis?. *Chest*, *122*(4), 1234-1239.
3. Boivin, G., Abed, Y., Pelletier, G., Ruel, L., Moisan, D., Côté, S., ... & Anderson, L. J. (2002). Virological features and clinical manifestations associated with human metapneumovirus: a new paramyxovirus responsible for acute respiratory-tract infections in all age groups. *The Journal of infectious diseases*, *186*(9), 1330-1334.
4. Braman, S. S. (2006). Chronic cough due to chronic bronchitis: ACCP evidence-based clinical practice guidelines. *Chest*, *129*(1), 104S-115S.
5. Buhagiar, B. (2009). Acute bronchitis.
6. Chang, A. B., Redding, G. J., & Everard, M. L. (2008). Chronic wet cough: protracted bronchitis, chronic suppurative lung disease and bronchiectasis. *Pediatric pulmonology*, *43*(6), 519-531.

7. Denguezli, M., Daldoul, H., Harrabi, I., Gnatiuc, L., Coton, S., Burney, P., &Tabka, Z. (2016). COPD in nonsmokers: reports from the Tunisian population-based burden of obstructive lung disease study. *PloS one*, *11*(3), e0151981.

8. Doke, P. P. (2023). Chronic respiratory diseases: a rapidly emerging public health menace. *Indian Journal of Public Health*, *67*(2), 192-196.

9. Fletcher, C. M., Elmes, P. C., Fairbairn, A. S., & Wood, C. H. (1959).

10. Irwin, R. S., Curley, F. J., & Bennett, F. M. (1993). Appropriate use of antitussives and protussives: a practical review. Drugs, 46, 80-91.

11. Karunanayake, C. P., Rennie, D. C., Ramsden, V. R., Fenton, M., Kirychuk, S., Lawson, J. A., ... & First Nations Lung Health Project Research Team. (2017). Bronchitis and its associated risk factors in first nations children. *Children*, *4*(12), 103.

12. Kim, V., & Criner, G. J. (2013). Chronic bronchitis and chronic obstructive pulmonary disease. *American journal of respiratory and critical care medicine*, *187*(3), 228-237.

13. Kinkade, S., & Long, N. A. (2016). Acute bronchitis. *American family physician*, *94*(7), 560-565.

14. Knutson, D., & Braun, C. (2002). Diagnosis and management of acute bronchitis. *American family physician*, *65*(10), 2039-2045.

15. Longe, J. L. (2015). The Gale encyclopedia of medicine.

16. Macfarlane, J., Holmes, W., Gard, P., Macfarlane, R., Rose, D., Weston, V., ... & Myint, S. (2001). Prospective study of the incidence, aetiology and outcome of adult lower respiratory tract illness in the community. *Thorax*, *56*(2), 109-114.

17. Mannino, D. M., Gagnon, R. C., Petty, T. L., & Lydick, E. (2000). Obstructive lung disease and low lung function in adults in the United States: data from the National Health and Nutrition Examination Survey, 1988-1994. *Archives of internal medicine*, *160*(11), 1683-1689.

18. Mejza, F., Gnatiuc, L., Buist, A. S., Vollmer, W. M., Lamprecht, B., Obaseki, D. O., ... &Devchakke, S. (2017). Prevalence and burden of chronic bronchitis symptoms: results from the BOLD study. *European Respiratory Journal*, *50*(5).

19. Mishra, J., Acharya, S., Taksande, A. B., Prasad, R., Munjewar, P. K., Wanjari, M. B., ... & Wanjari, M. (2023). Occupational risks and chronic obstructive pulmonary disease in the Indian subcontinent: a critical review. *Cureus*, *15*(6).

20. Mukherjee,T. K. & Indian Institute of Science Education and Research. (2009). Bronchitis: causes and treatment. In Handbook of Pulmonary Diseases: Etiology (Chapter 3). Nova Science Publishers, Inc.

21. Musalli, A. M., Alshehri, W. A., Abdulrahman, K. M., Alfawzan, M. A. M. A., Defullah, A. J., Almalki, D. A. D. A., ... & Albarqawi11, W. M. (2022). A Review of Respiratory System Diseases: Causes, Symptoms, and Treatments. *Migration Letters*, *19*(S8), 103-113.

22. Oswald, N., Harold, J., & Martin, W. J. (1953). Clinical pattern of chronic bronchitis. *The Lancet*, *262*(6787), 639-643.

23. Shawarb, N., Badrasawi, M., Qaoud, H. A., & Hussein, F. (2023). An ethno-botanical study of medicinal plants used for the management of respiratory tract disorders in northern parts of Palestine. *BMC Complementary Medicine and Therapies*, *23*(1), 387.

24. Smith, M. P., Lown, M., Singh, S., Ireland, B., Hill, A. T., Linder, J. A., ... & Weinberger, M. (2020). Acute cough due to acute bronchitis in immunocompetent adult outpatients: CHEST Expert Panel Report. *Chest*, *157*(5), 1256-1265.

25. Sutradhar, I., Gupta, R. D., Hasan, M., Wazib, A., & Sarker, M. (2019). Prevalence and risk factors of chronic obstructive pulmonary disease in Bangladesh: a systematic review. *Cureus*, *11*(1).

26. Tomar, R., Yadav, B., Singh, H., Hetalben, A., Khanduri, S., Sharma, B. S., ... & Dhiman, K. S. (2022). A clinical study to evaluate the efficacy of Ayurvedic intervention in management of chronic bronchitis. *Journal of Research in Ayurvedic Sciences*, *6*(3), 101-108,

27. Wark, P. (2015). Bronchitis (acute). *BMJ clinical evidence*, *2015*, 1508.

28. Wenzel, R. P., & Fowler III, A. A. (2006). Acute bronchitis. *New England journal of medicine*, *355*(20), 2125-2130.

29. Widysanto, A., Goldin, J., & Mathew, G. (2025). Chronic bronchitis. In *StatPearls [Internet]*. StatPearls Publishing.

Dendrophthoe Falcata: Phytochemical and Pharmacological Profile

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ABSTRACT

The plant species that make up the mistletoe family, Loranthaceae, are hemiparasites. A big, bushy hemiparasite with an evergreen stem, Dendrophthoe falcata. Through penetrating roots known as haustoria, it can harvest sustenance from the host trees. This epiphytic parasite is typically present on numerous host plants all over the globe and causes significant harm to economically important cultivated plants as well as plants grown on various hosts in India. The plant species Dendrophthoe falcata, also known as "Vanda," is a member of the Loranthaceae family. This plant is a permanent parasite that grows on another host plant. It is employed in ethnomedicine to treat skin problems, impotence, paralysis, ulcers, and impotence. Additionally, this plant is holy. The Santalales genus Dendrophthoe falcata is used in conventional medicine to address paralysis, impotence, asthma, ulcers, and skin issues. It is indigenous to Indo-China, Australia, India, Sri Lanka, and Thailand. Numerous of its chemical constituents, many of which have medicinal value, include carbohydrates, alkaloids (leaf), phytosterols, fixed oils, phenolic compounds, gallic acid, ellagic acid, triterpenes, quercetin, quercetrin, rutin, chebulinic acid, -amyrin acetate, -sitosterol, and stigmasterol. According to studies, it can assist with menstrual issues, ulcer treatment.

***Keywords**: Dendrophthoe falcata, ellagic acid, hemiparasite, menstrual issues.*

1. INTRODUCTION

A massive, bushy parasitic shrub called Dendrophthoe falcata Ettingsh (Family: Loranthaceae) has ovoid-shaped fruit, thick, frequently opposite leaves with orange-red or crimson blooms (CSIR, 1952). Due to their availability as prescription drugs or nutritional supplements in the majority of locations, medical plants are attracting more and more interest from academics nowadays (Jalali et al., 2022 & Jiang et al., 2022). The Indian medical system has the most extensive documentation on DF's ethnomedical applications. For instance, the Indian Ayurvedic medical system refers to DF as "Vanda," "Vrksadani," and "Vrksaruha," and it is known to have therapeutic benefits on psychosis, leucorrhea, contraception, bone fractures, and menstrual abnormalities (Khatoon et al., 2011; Madhuri et al., 2013 & Jain et al., 2016). Indigenous medicine uses the entire DF for the treatment of diseases that are cooling, bitter, astringent, narcotic, aphrodisiac, cancer-causing, and diuretic (Bhagat et al., 2019; Reddy et al., 2019 & Shalini et al., 2019a). It is also effective in treating respiratory tuberculosis, allergies and asthma, problems with menstruation, inflammation wounds, ulcers, kidney and vesical calculi, and vitiated kapha and the pitta conditions(Anarthe at al., 2008; Sastry, 1952 & Pattanayak et al., 2008). Approximately thirty-one different species of the genus Dendrophthoe are found in tropical regions of Africa, Asia, and Australia (Flora of China, 2003), with 7 of those species discovered in India were examined. D. falcata has robust blooms, thick coriaceous leaves that are differ in appearance, and grey bark (SPMBGP, 2003 & CSIR, 2002). It has been demonstrated that the plant decoction that is utilised by women as an anti-fertility drug possesses cancerous properties (Nadkarni, 1993). Skin problems are treated using leaf paste. Its paste is used to treat boils, realign broken bones, and remove pus. Scientific evidence supports the plant's antilithiatic, diuretic medication, cytotoxic, and immunomodulatory actions(CSIR, 1993; Pattanayak et al., 2009; Allekutty et al., 1993; & Mary et al., 1993).

1.1 Classification

Table 1: Showing the Scientific Classification

Kingdom	Plantae
Family	Loranthaceae
Genus	*Dendrophthoe*
Species	*falcata*

Botanical name	*Dendrophthoe falcata (*L.F) Etting
Common name	honey suckle mistletoe, showy mistletoe, giant mistletoe

1.2 Common Names:

Sr. No.	Regional Names	Common Names
1.	**Sanskrit**	Vrksadani, Bandaka, Vrksaruha, Samharsa
2	**Bengali**	Maandaa
3	**English**	Mistletoe
4	**Gujrati**	Baando
5	**Hindi**	Bandaa
6	**Kannada**	Bandanike, Bandhulu
7	**Malayalam**	Ittikkanni, Itil
8	**Marathi**	Baandagul, Banda
9	**Oriya**	Vrudhongo
10	**Punjabi**	Pulluri
11	**Tamil**	Baadanikaa, Jiddu
12	**Telugu**	Jeevakamu

1.3 Geographical distribution

D. falcata, frequently referred to as Loranthus longiflorus Desr., acts as a parasitic perennial climbing plant made of wood. Tropical regions are home to it, particularly in India, Sri Lanka, Thailand, China, Australia, Bangladesh, Malaysia, and Myanmar. Serious parasites of both angiosperms and gymnosperms, including a wide range of economically important plants, are Loranthus species. Currently, Loranthus spp. cause commercial plant destruction in many regions of the world. In deciduous woods all throughout India, a huge, bushy parasite called D. falcata thrives on a variety of host plants. Seven geographic regions were used to categorise the

distribution of the genus Loranthaceae worldwide: Africa, South America, Asia, Malaysia east of the Wallace's line (New Guinea), Malaysia west of Wallace's line, Australia, and New Zealand (Russell et al., 2007).

Figure No. 1: Showing the leaves of *Dendrophthoe Falcata*

1.4 Traditional and medicinal uses

As an aphrodisiac, pungent, narcotic, diuretic, and for the treatment of respiratory tuberculosis, asthma, menstrual problems, swellings, wounds, and ulcers, Warrier (1993) noted that the entire plant is utilised widely in traditional systems of medicine. The medication serves as a diuretic for urinary disorders and calculi. It is prescribed for conditions including diarrhoea, dysentery, insanity, epilepsy, cardiac issues, blood illnesses, convulsions, and nervous system ailments (Warrier et al., 1993; CSIR ,1952 ; Panday , 2004)]. It is used to treat menstrual irregularities, wounds, renal and the bladder stone prevention, haemorrhage, miscarriage, and pregnancy-related abortion. In Ayurveda, plants cultivated on Ficus fistula hosts are utilised for foetal development. Vatta, kapha, and pitta all use it. This plant is used to prevent third-month pregnancies from ending in abortions. Leaf paste is administered for abortion as well as skin conditions (Raut et al., 2009; Bhattarai et al., 1991; Siwakoti et al., 2000).

1.5 Macroscopic characters

Thick, coriaceous, mostly opposite leaves measure 7.5 to 18 by 2 to 10 cm, have an oblong to oblanceolate shape, and are petiolate, exstipulate, and decussate. A broad, bushy, typically

glabrous branch that is parasitic, with smooth, grey bark, thin, 2 mm to 2.5 cm thick twigs of aerial branches, a touchably rough stem, irregular fractures, dark brown cracked surfaces, and no discernible flavour or colour. Flowers are arranged in short, spreading, stout, unilateral racemes that are sometimes two from an axil. The bract is 1.6 millimetres long, roughly elliptical, subacute concave, and orange red in hue. Calyx is around hoary and 4 mm long. Corollas range in length from 2.5 to 5 cm, are divided at the rear, and have a curving, slightly expanded tube. Berry 8 to 13 mm long, ovoid to oblong, pink, smooth, and topped with a calyx in the shape of a cup (CSIR ,1952; GOI, 2009 & Baheti et al., 2010)

1.6 Microscopic character

To identify healthy plants and components for the planned study, plant specimens were collected. Cut and eliminated from the plant, the relevant leaf samples were then preserved in FAA (formalin-5ml+acetic acid-5ml+70% ethyl alcohol-90ml). The specimens were dehydrated employing various grades of tertiary butyl alcohol after being fixed for 24 hours. The samples were poured into blocks of paraffin. The rotary microtome was used to segment the paraffin-embedded specimens. The segment had a thickness of 10–12 micro metres. Toluidine blue was used to stain the pieces. Paradermal sections, leaf cleaning with 5% NaoH, or epidermal pealing by partial maceration are used to analyse the stomatal morphology, venation pattern, and trichome distribution. After being stained, various powered materials were cleaned with NaOH and mounted in glycerine medium (Johansen, 1940 & Mathew 1983).

1.7 Phytochemicals

1.7.1 Leaves: Leaf include tannins made up of gallic and chebulinic acids, as well as flavonoids including quercetin and quercitrin.

1.7.2 Stem: The fresh shoots have a tannin content of around 10%, and the stem has sitosterol, stigmasterol, oleonolic acid, and its methyl ester acetate.

1.7.3 Root: The bark contains catechin and leucocynidin (API, 2009 & Anarthe et al., 2010).

Table 2: Showing the details of Phytoconstituents

Name	IUPAC Name	Formula
Beta-Sitosterol	17-(5-ethyl-6-methyl-heptan-2-yl)-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H cyclopenta[a]phenanthren-3-ol	$C_{29}H_{50}O$

Stigmasterol	17-(4-ethyl-1,5-dimethyl-hex-2-enyl)-10,13-dimethyl-,2,4,5,6,7,8,9,10,11,12,13,14,15,16,17-hexadecahydrocyclopenta[a] phenanthren-3-one	$C_{29}H_{48}O$
beta-Amyrin acetate	(4,4,6a,6b,8a,11,12,14b-octamethyl-2,3,4a,5,6, 7,8,9,10,11,12,12a,14,14a-tetradecahydro -1H-picen-3-yl) acetate	$C_{32}H_{52}O_2$
Oleanolic acid	10-hydroxy-2,2,6a,6b,9,9,12a-heptamethyl-1,3,4,5,6,6a,7,8,8a,10,11,12,13,14b-tetradecahydropicene-4a-carboxylic acid	$C_{30}H_{48}O_3$

2. REVIEW OF RELATED STUDIES

2.1 Pharmacological activities

2.1.1 Wound healing activity:

Fresh leaf and stem have traditionally been employed to make a paste with water that is administered topically to damaged areas to cure wounds. The aerial parts' ethanolic extract demonstrated strong wound-healing potential. Rat excision and incision wound models were used to assess the healing effectiveness of an ethanol extract of aerial parts. The wound contracting and enhanced tensile strength of the extract of Dendrophthoe falcata demonstrated the extract's powerful wound healing potential (Ayyanar et al., 2009; Pattanayak , 2008 & Chaitanya et al., 2010).

2.1.2 Anti-diabetic activity:

Alloxan was used to develop diabetes in rats at a level of 70 mg/kg. When compared to a diabetic control group, it was shown that the ethanolic extract of D. falcata leaves (70%) at 300 mg/kg significantly (p 0.01) reduced the raised blood glucose level. Additionally, it is said to have diuretic, antilithiatic, and antihypertensive properties (Tenpe et al., 2008; Balaram et al., 1981 & Alkutti et al.,1993).

2.1.3 Anti-bacterial activity:

Muller-Hinton plates (Hi-media) are made in the needed quantity following the manufacturer's instructions. According to Bergey's manual of systematic bacterial categorization, the following pathogens have been isolated from nearby hospitals and identified. Escherichia coli,

Staphylococcus sp., and Pseudomonas sp. were chosen as the pathogens for the antibacterial activity. The murky culture solution was dipped into using a sterilised cotton swab. By streaking twice more and turning, the Muller-Hinton agar plate's dry surface was infected. For all the pathogens, gentamycin was employed as the positive control. After evaporating the solvent, 2µl of crude D. falcata extract was added to the sterile disc. After drying, the plates were left to incubate at 35 oC for 1 hour to allow for proper diffusion, and then moved to as incubated at 37 oC for 2 hours for bacterial cultures. The disc's clear inhibitory zone's diameter was used to measure the antibacterial activity (Bauer et al., 2009).

Anti-fungal activity: By using the disc diffusion technique, the antifungal activity of the D. falcata extracts was assessed against Aspergillus niger, Aspergillus flavus, and Penicillium. As a benchmark, fluconazole (10mcg disc-1) was employed. The seeded sabouraud dextrose agar medium, which was previously cultured with the test organism, was put aseptically on the filter paper disc impregnated with different extracts (20mg ml-1), and the fluconazole disc. This medium was then incubated at 37 °C for 48 hours. The zone of inhibition (in mm) of D. falcata extracts was measured to determine their antifungal activity (Rajasekaran et al, 2009).

2.1.4 Effect of fertility:

Kaempferol, which was extracted from the stems of DF, was given orally to rats for 60 days at a dose of 50 mg/rat/day, resulting in reduced sperm motility and density as well as a noticeably lower level of serum testosterone than the healthy control group (Kachhawa et al., 2011b). Particular extracts have been shown to offer potential therapeutic benefits for reproductive issues. Follicle-stimulating hormone (FSH) and progesterone levels in female rats were assessed employing the at random evidence examiner the analyser and oral administration of the methanolic extract of DP leaves (100 mg/kg). The results showed values of 9.28 miu/mL 6.72 miu/mL and 33.55 nmol/L 13.96 nmol/L, respectively (Mochamad et al., 2014). A reduction in the number of litters born following postcoital testing indicated anti-implantation action when the rats were orally administered with the ethanol extract of the aerial portions of DF (250 mg/kg-950 mg/kg) (Pattanayak et al., 2009b). Additionally, oral treatment of the methanolic extract of DF stems at 200 mg/rat/day might decrease the weights of reproductive organs, sperm count, and sperm motility in male rats compared to the vehicle-treated control group, resulting to sterile status (Gupta et al.,2008). the context of contrast to the standard drug group [lonidamine(1-(2,4-dichlorobenzyl)-1H-indazole-3carboxylic acid], the methanol extract of DF

stems caused a decrease overall protein, sialic acid, and glycogen content in the testicles when given orally to male rats at a dose of 200 mg/rat/day. Comparatively to the untreated control group, oral treatment of a methanol extract of DF stems (200 mg/kg) resulted in lower sperm motility, density, and serum testosterone levels as well as degenerative alterations in the varicocele in male albino rats (Gupta et al., 2007). Additionally, the oral administration of the chloroform portion of DF stems at a dose of 50 mg daily revealed the suppression of sperm density and motility in the epididymal tail, along with a reduction in protein and sialic acid in the testis and cauda epididymis and an increase in testicular cholesterol when compared to the untreated group (Kachhawa et al., 2011a).

2.1.5 Total antioxidant capacity

Prieto et al.'s technique of measurement for total antioxidant capacity was used. In a nutshell, 100 g of the extract and 100 g of ascorbic acid (used as the standard) were taken in 0.1 mL of alcohol and mixed separately with 1.9 mL of the reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). The tubes were sealed, and they were kept at 95°C for 90 minutes in a thermal block. The absorbance of the aqueous solution of each sample was evaluated at 695 nm in comparison to a blank after the samples had cooled to room temperature. 1.9 mL of reagent solution and the appropriate amount of the sample's solvent made up a typical blank solution, which was incubated in the same manner as the other samples. Water-soluble antioxidant capabilities are reported as ascorbic acid equivalents for materials whose composition is unknown. The standard graph of ascorbic acid was used to compute the equivalents of ascorbic acid. Values from the experiment are represented as ascorbic acid equivalents in g/mL of extract and were carried out in triplicate (Kachhawa et al., 2011a & Prieto et al., 1999).

2.1.6 Anti-convulsant activity

The most frequently used animal model for evaluating antiepileptic medications is the maximal electroshock test. The results of the current study showed that Dendrophthoe falcata ethanolic extract had anticonvulsant activity because it reduced MES-induced tonic seizures. Using antiepileptic medications that have been clinically proven to be effective, the MES test finds compounds that have action against generalised tonic-clonic seizures. It has frequently been suggested that the maximal electroshock test can predict anticonvulsant drug effects against partial seizures in addition to identifying drug activity against generalised tonic-clonic seizures.

Dendrophthoe falcata's ethanolic extract's anticonvulsant efficacy at 500 mg/kg in MES models suggests that DFEE stem may cause tonic-clonic seizures. The current experiment also showed that, at anticonvulsant doses, DFEE caused motor impairment and reduced spontaneous locomotor activity. Due to the high rutin concentration that gives it its anticonvulsant properties, this investigation has also received research attention. Several chemical components of plant source, such as flavonoids and triterpenoids, are said to have muscle-relaxing properties (Shariati et al., 2008 & Hossein et al., 2003).

2.1.7 Anti-microbial activity

The culture medium diffusion method was used to test the antimicrobial activity of the crude extract and each fraction. With a few minor adjustments, this approach was borrowed from Bisnu. Staphylococcus aureus ATCC-25923, Staphylococcus epidermidis FNCC-0048, Escherichia coli ATCC-11229, and Streptococcus mutans were the four microorganisms employed in this study. Chloramphenicol was employed as the positive control, and 10% of DMSO (dimethyl sulfoxide), a solvent, was used as a negative control. A Muller Hinton culture plate was inoculated with the examination bacteria from 100 L, and the plate was smoothed with drigalsky. Each sample's solution was put on top of the culture medium, and the paper disk was submerged into it for five minutes before being incubated at 370°C for 12 hours. After 12 h the incubation processes the zone of inhibition surrounding the disks was calculated in millimeter scale. Each sample underwent four sequential dilutions (0.01; 0.1; 0.5 and 1.0% w/v). Three times were used to measure the object (Bishnu et al., 2015).

2.1.8 Anti-diarrheal activity

According to the procedure outlined by Shoba & Thomas, the clinical study was carried out (Shoba et al., 2001). Briefly, fourteen groups consisting of six mice each were created from mice that had been fasting for 24 hours. By administering 0.5 cc of castor oil to every animal, every animal was originally tested. The last trial only included individuals who had diarrhoea. Groups III, IV, and V was given oral doses of the aqueous extracts (50, 100, and 200 mg/kg), ethanol extract (50, 100, and 200 mg/kg), chloroform extract (50, 100, and 200 mg/kg), and petroleum ether extract (50, 100, and 200 mg/kg), respectively. Group I received 1% CMC (10 ml/kg, p.o.), Group II received loperamide (10 mg/kg, p. Each animal received 0.5 cc of castor oil orally an hour after oral consumption. The separate digestive cages, whose floors were covered in blotting paper, were used to house every creature in its assigned group. This document was modified

after one hour and monitored for four hours. When compared to the control group, the total quantity and weight of stools—both diarrheal and non-diarrheal—counted in each group were compared, and the findings were represented as a percentage of decreased diarrheal output (stool output).

Inhibition of stools (%) = × 100

Where, T0 = Total number of stools in control

group, T1 = Total number of stools in test group.

2.1.9 Anti-cancer activity

Animal models and cancer cell lines both show anti-cancer activity. High cytotoxic effects against human breast cancer cells (MCF-7) are present in ethanolic and aqueous extracts from the stem of D. falcata (Dashora et al., 1952). D. falcate's ethanol extract showed mice with EAC strong anti-cancer efficacy. It was discovered that this anti-cancer action resembled that of cisplatin (Dashora et al., 2011). With a concurrent improvement in antioxidant status, D. falcata hydroalcoholic extract demonstrated a role of defence against DMBA (7,12-dimethylbenz(a)anthracite)-induced breast carcinogenesis. Therefore, in addition to the cytotoxic impact, the antioxidant activity of D. falcata extract may also play a role in the cancer-fighting capacity that has been found (Pattanayak et al., 2010). Different parts of D. falcate contain phytochemicals such as flavonoids (quercetin, catechin), tannins (gallic acid, chebulinic acid), oleonolic acid, -amyrin-0-acetate, leucocynidin, and sterols (-sitosterol and stigmasterol), some of which have been shown to have anti-cancer properties (Manthri et al., 2011).

2.1.10 Anti-oxidant activity

Each specimen was subjected to a free radical scavenger technique test for antioxidant activity. A source of free radicals used in this procedure was DPPH (2,2-diphenyl-1-picrylhydrazyl). Five millilitres each of the sample (in various ratios ranging from 100 to 3,125 g/mL) and the positive control (ascorbic acid in various concentrations ranging from 6.25 to 0.390 g/mL) were combined with five millilitres of the DPPH mixture in methanol (0.12 mM), and the mixture was then let to remain at room temperature for thirty minutes. Using spectronic 20 (Genesys), absorbance was measured at 516 nm. We compared the sample's and the control solution's DPPH absorption rates. In three replications, each sample was examined. A lower proportion of DPPH was used to quantify antioxidant activity comparison to control, and IC50 may be derived by measuring inhibitory activity (Hanumantharaju et al., 2010).

3. Conclusion

The therapeutic potential of *Dendrophthoe falcata* is supported by its rich phytochemical profile, which includes alkaloids, flavonoids, phenolic compounds, triterpenes, phytosterols, and bioactive constituents such as quercetin, rutin, gallic acid, ellagic acid, β-sitosterol, and stigmasterol. These compounds are known for their antioxidant, anti-inflammatory, antimicrobial, and ulcer-healing properties, providing a scientific basis for its traditional uses. In conclusion, while *Dendrophthoe falcata* poses ecological and economic challenges as a parasitic species, it also emerges as a valuable medicinal resource with promising pharmacological applications. Further systematic research, including phyto-chemical standardization, pharmacological validation, and toxicity studies, is essential to fully explore and utilize its therapeutic potential while balancing its management in agro forestry systems.

4. DECLARATIONS

4.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

4.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

4.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

5. REFERENCE

1. Council of Scientific and Industrial Research. (1952). *The Wealth of India: Raw materials — A dictionary of Indian raw material and industrial products* (Vol. 3, D–E, pp. 34–35). New Delhi.
2. Jalali, J., & Rahbardar, M. G. (2022). Ameliorative effects of *Portulaca oleracea* L. (purslane) on the metabolic syndrome: A review. *Journal of Ethnopharmacology, 299*, 115672. https://doi.org/10.1016/j.jep.2022.115672.

3. Jiang, M. Y., Zhao, S. J., Yang, S. S., Lin, X., He, X. G., Wei, X. Y., et al. (2022). An "essential herbal medicine" — licorice: A review of phytochemicals and its effects in combination preparations. *Journal of Ethnopharmacology, 249*, 112439. https://doi.org/10.1016/j.jep.2019.112439

4. Khatoon, S., Singh, H., & Goel, A. (2011). Use of HPTLC to establish the chemotype of a parasitic plant, *Dendrophthoe falcata* (Linn. f.) Etting. (Loranthaceae), growing on different substrates. *Journal of Planar Chromatography—Modern TLC, 24*(1), 60–65. https://doi.org/10.1556/jpc.24.2011.1.12

5. Madhuri, M., Deepthi, B., Vinatha, V., & Chmm, P. R. (2013). Analgesic activity of aqueous and alcohol root extracts of shoots of *Dendrophthoe falcata*. *International Journal of Research in Phytochemistry & Pharmacology, 3*(1), 54–56.

6. Jain, A., & Sharma, M. (2016). In-vitro antimicrobial screening of *Dendrophthoe falcata* (L.f.) Ettingsh. *International Journal of Current Microbiology and Applied Sciences, 5*(12), 594–602. https://doi.org/10.20546/ijcmas.2016.512.064

7. Bhagat, V. C., & Kondawar, M. S. (2019). Antitubercular potential of *Dendrophthoe falcata* (L.) and *Tridax procumbens* (L.) plant extracts against H37Rv strain of *Mycobacterium tuberculosis*. *International Journal of Pharmaceutical Sciences and Research, 10*(1), 251–259. https://doi.org/10.13040/ijpsr.0975-8232.10(1).251-59

8. Reddy, P. S., Sowmya, B., Sravani, N., Sandhya, P., & Mohan, C. K. (2019). Evaluation of diuretic potential of petroleum ether extract of *Dendrophthoe falcata* leaves in Wistar rats. *Asian Journal of Pharmacy and Pharmacology, 5*(6), 1086–1090. https://doi.org/10.31024/ajpp.2019.5.6.2

9. Shalini, K. S., Yengkhom, O., Subramani, P. A., & Dinakaran, M. R. (2019a). Polysaccharide fraction of *Dendrophthoe falcata* leaves enhances innate immune responses and disease resistance in *Oreochromis niloticus*. *International Journal of Research in Pharmaceutical Sciences, 10*(1), 56–64. https://doi.org/10.26452/ijrps.v10i1.1780

10. Anarthe, S. J., Bhalke, R. D., Jadhav, R. B., & Surana, S. J. (2008). In vitro antioxidant activities of methanol extract of *Dendrophthoe falcata* Linn. stem. *Biomed, 3*(2), 182–189.

11. Sastry, B. N. (1952). *The Wealth of India (Raw Materials)* (Vol. III, p. 34). CSIR.

12. Pattanayak, S. P., & Sunita, P. (2008). Wound healing, antimicrobial and antioxidant potential of *Dendrophthoe falcata* (L.f.) Ettingsh. *Journal of Ethnopharmacology, 120*, 241–247.

13. Science Press & Missouri Botanical Garden Press. (2003). *Flora of China* (Vol. 5, p. 227). https://www.efloras.org

14. Council of Scientific and Industrial Research. (2002). *The Wealth of India: Raw materials* (Vol. 3, 4th ed., p. 588).

15. Nadkarni, K. M. (1993). *Indian materia medica* (Vol. I, p. 750). Popular Prakashan.

16. Council of Scientific and Industrial Research. (1969). *The Wealth of India: Raw materials* (Vol. III, pp. 34–36).

17. Pattanayak, S. P., & Mitra Mazumder, P. (2009). Assessment of neurobehavioral toxicity of *Dendrophthoe falcata* (L.f.) Ettingsh in rats by functional observational battery after subacute exposure. *Pharmacognosy Magazine, 5*, 98–105.

18. 18. Allekutty, N. A., Srinivasan, K. K., Gundu, R. P., Udupa, A. C., & Keshawamurthy, K. R. (1993). Diuretic and antilithiatic activity of *Dendrophthoe falcata*. *Fitoterapia, 64*(5), 325–331.

19. Mary, K. T., Kuttan, R., & Kuttan, G. (1993). Cytotoxicity and immunomodulatory activity of *Loranthus* extract. *Amala Research Bulletin, 13*, 53–58.

20. Russell, R. V., & Nickrent, D. L. (2007). The biogeographic history of Loranthaceae. *Darwiniana, 45*, 34–54.

21. Warrier, P. K., Nambiar, V. P. K., & Ramankutty, C. (1993). *Indian medicinal plants: A compendium of 500 species* (2nd ed.). Orient Longman.

22. Council of Scientific and Industrial Research. (1952). *The Wealth of India: Raw materials — A dictionary of Indian raw material and industrial products* (Vol. 3, D–E, pp. 34–35). New Delhi.

23. Panday, G. (2004). *Dravyaguna vijnana: Material media – Vegetable drugs* (Vol. 3, pp. 334–336). Chowkhamba Krishnadas Academy.

24. Raut, D. N., Pal, S. C., & Mandal, S. C. (2009). Anthelmintic potential of *Dendrophthoe falcata* Etting (L.f.) leaf. *International Journal of Pharmaceutical Research and Development, 6.*

25. Bhattarai, N. K. (1991). Folk herbal medicines of Makawanpur district, Nepal. *International Journal of Pharmacognosy, 29*(4), 284–295.

26. Siwakoti, M., & Siwakoti, S. (2000). Ethnobotanical uses of plants among the Satar tribes of Nepal. In J. K. Maheshwari (Ed.), *Ethnobotany and medicinal plants of the Indian subcontinent* (pp. 79–108). Scientific Publishers.

27. Government of India. (n.d.). *Ayurvedic Pharmacopoeia of India* (Vol. 5, pp. 212–214).

28. Baheti, D. G., Kadam, S. S., Namdeo, A., Shinde, P. B., Agrawal, M. R., & Argade, P. D. (2010). Pharmacognostic screening of *Dendrophthoe falcata*. *Pharmacognosy Journal, 2*(6), 128–131.

29. Johansen, D. A. (1940). *Plant microtechnique*. McGraw-Hill.

30. Mathew, K. M. (1983). *The flora of Tamil Nadu Karnatic* (Vol. 1, p. 688). Polypetalae.

31. Ayurvedic Pharmacopoeia. (n.d.). *Vol. 5, Part I*, pp. 181–189.

32. Anarthe, S., et al. (2010). Pharmacognostic standardisation and physicochemical evaluations of stems of hemiparasite *Dendrophthoe falcata* Linn. *RJPBCS, 1*(2).

33. Ayyanar, M., & Ignacimuthu, S. (2009). Herbal medicines for wound healing among tribal people in Southern India: Ethnobotanical and scientific evidence. *International Journal of Applied Research in Natural Products, 2*(3), 29–42.

34. Pattanayak, S. P. (2008). Wound healing, antimicrobial and antioxidant potential of *Dendrophthoe falcata* (L.f.) Ettingsh. *Journal of Ethnopharmacology, 120*(2), 241–247.

35. Chaitanya Sravanthi, K., Manthri, S., Srilakshmi, S., & Ashajyothi, V. (2010). Wound healing herbs – A review. *International Journal of Pharmacy & Technology*, *2*(4), 603–624.

36. Tenpe, C. R., Upaganlawar, A. B., Khairnar, A. U., & Yeole, P. G. (2008). Antioxidant, antihyperlipidaemic and antidiabetic activity of *Dendrophthoe falcata* leaves: A preliminary study. *Pharmacognosy Magazine, 4*(16, Suppl.).

37. Balaram, R., Raj, K. P. S., & Panchal, D. I. (1981**).** *Indian Drugs, 2***,** 183.

38. Alkutti, N. A., Srinivasan, K. K., Gundu, R. P., Udupa, A. C., & Keshavamurthy, K. R. (1993). Diuretic and antilithiatic activity of *D. falcata***.** *Fitoterapia, 64***,** 325–331.

39. Bauer, A. W., Kirby, M. D. K., & Sheris, J. C. (1986). Antibiotic susceptibility testing by standardized single disc method. *Journal of Clinical Pathology, 45***,** 149–158.

40. Rajasekaran, A., et al. (2009). *International Journal of Chemical Technology Research, 1*(3).

41. Kachhawa, J. B., Gupta, R. S., & Sharma, K. K. (2011b). Ethnopharmacological evaluation of male contraceptive efficacy of *Dendrophthoe falcata* in albino rats. *Planta Medica, 77*(12), 1316. https://doi.org/10.1055/s-0031-1282427

42. Mochamad, L., & Hermanto, B. (2014). *Dendrophthoe pentandra* methanolic leaf extract increases progesterone levels in female rats. *Universa Medicina, 33*(2), 100–108.

43. Pattanayak, S. P., & Mazumder, P. M. (2009b). Effect of *Dendrophthoe falcata* (L.f.) Ettingsh on female reproductive system in Wistar rats: A focus on antifertility efficacy. *Contraception, 80*(3), 314–320. https://doi.org/10.1016/j.contraception.2009.03.001

44. Gupta, R. S., & Kachhawa, J. B. S. (2008). Contraceptive and toxicological evaluation of *Dendrophthoe falcata* stem extract in male albino rats. *Journal of Herbs, Spices & Medicinal Plants, 13*(3), 37–46. https://doi.org/10.1300/J044v13n03_04

45. Gupta, R. S., & Kachhawa, J. B. S. (2007). Evaluation of contraceptive activity of methanol extract of *Dendrophthoe falcata* stem in male albino rats. *Journal of Ethnopharmacology, 112*(1), 215–218. https://doi.org/10.1016/j.jep.2007.02.022

46. Kachhawa, J., Gupta, R., & Sharma, K. (2011a). Evaluation of contraceptive potential of isolated fractions from *Dendrophthoe falcata* stem methanol extract in male albino rats**.** *Planta Medica, 77*(5), 132. https://doi.org/10.1055/s-0031-1273661

47. Prieto, P., Pineda, M., & Aguilar, M. (1999). Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: Specific application to the determination of vitamin E_1 . *Analytical Biochemistry, 269,* 337–341.

48. Shariati Rad, S., Nassiri Asl, M., & Zamansoltani, F. (2008). Anticonvulsant effects of rutin in a rat model of absence seizure: A novel compound to treat seizure. *Annals of General Psychiatry, 7*, S219.

49. Hossein, H., Ramezani, M., & Namjo, N. (2003). Muscle relaxant activity of *Elaeagnus angustifolia* L. fruit seeds in mice. *Journal of Ethnopharmacology, 84,* 275–278.

50. Bishnu, P. M., Pankaj, B., Pratibha, A., Kashi, R. G., Sanjiv, N., & Nabara, D. (2015). *BioMed Research International, 2015,* 1–6.

51. Shoba, F. G., & Thomas, M. (2001). Study of antidiarrhoeal activity of four medicinal plants in castor oil–induced diarrhea. *Journal of Ethnopharmacology, 76*, 73–76.

52. Dashora, N., Sodde, V., Prabhu, K. S., & Lobo, R. (2011). *International Journal of Cancer Research, 7*, 47–54.

53. Dashora, N., Sodde, V., Bhagat, J., Prabhu, K. S., & Lobo, R. (2011). *Pharmaceutical Crops, 2*, 1–7.

54. Pattanayak, S. P., & Mazumder, P. M. (2010). *Comparative Clinical Pathology, 20*, 381–392.

55. Manthri, S., Kota, C. S., & Talluri, M. (2011). *Phytology, 3*, 18–25.

56. Hanumantharaju, N., Shashidhara, S., Rajasekharan, P. E., & Rajendra, C. E. (2010). *International Journal of Pharmacy and Pharmaceutical Sciences, 2*(4), 72–75.

Are Millets Truly Healthy? A Review of Bioactive Compounds and Health Outcomes

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ABSTRACT

The earliest known cereals are millets, which are described as having been present in the early stages of human civilization. Millets provide several health advantages. Millets are a rich source of nutrients, providing benefits for controlling various diseases, One of the most important health benefits of millets is their low glycaemic index, which helps in regulating blood glucose levels and makes them extremely appropriate for individuals with diabetes. The high amount of fibre content in millets aids in digestion, improves gut health, and helps in preventing constipation and other gastrointestinal disorders. Regular consumption of millets has been associated with reduced cholesterol levels, improved cardiovascular health, and enhanced metabolic functions. Additionally, millets possess antioxidant and detoxifying properties that help in reducing oxidative stress and supporting overall well-being. Furthermore, millets are highly suggested for those with gluten sensitivity and celiac disease. Millets, a traditional and long-standing super food, is not only gluten-free but also rich in proteins, fibres, and complex carbs. India is home to several varieties of millets. Every kind of millet has distinct advantages. India is known for cultivating many varieties of millets, such as Jowar, Bajra, Ragi, Samai, Kuttu, Rajgira, and others.. With increasing awareness of sustainable agriculture and healthy eating habits, millets are gradually more recognized as climate-resilient, nutritious, and sustainable superfoods with promising future potential in food security and public health.

Keywords: *Millets, Civilization, Detoxification, Superfood, Celiac, Gluten sensitivity.*

1. INTRODUCTION

Projections indicate that the global diabetic population would increase by 51% by 2045, reaching 700 million individuals, compared to 463 million in 2019. Type 2 diabetes is expected to account for over 90% of the total cases. Approximately 87 percent of fatalities attributable to diabetes occur in low- and middle-income countries that have little diversity in their basic dietary sources (IDF, 2021). It is crucial to bear in mind that, apart from obesity and a lack of physical activity, the kind of food consumed has a substantial influence on diabetes. The primary sources of energy in emerging countries, such as maize, refined wheat, and rice, account for up to 80% of the total energy consumption (Anitha et al., 2019). In order to manage and avoid diabetes, it is essential to vary the primary components of one's diet and prioritize traditional, nutrient-rich, and low-glucose staples, particularly millets and sorghum, in many developing countries (Chandra et al., 2016).

By replacing basic foods with nutrient-dense and healthy alternatives, it is possible to reduce the prevalence of certain health problems and improve dietary variety (Amadou et al., 2013).Millets are well recognized for their low Glycaemic Index (GI), which may be beneficial in the control of diabetes. The thirteen globally available varieties of millets are sorghum, finger millet, pearl millet, proso millet, kodo millet, barnyard millet, brown top millet, foxtail millet, Guinea millet, Job's tears, fonio, and teff (Vetriventhan et al., 2020). India has easy access to all millets except for teff, fonio, and Job's tears. The Indian government officially classified millets as "Nutri Cereals" due to their recognized potential and importance in ensuring the country's food and nutritional security. Finger millet is prevalent in India. The composition includes two pseudo millets/pseudo cereals (Buckwheat and Amaranthus) as well as three primary millets (Sorghum, Pearl Millet, Finger Millet); and secondary millets (Foxtail Millet, Proso Millet, Kodo Millet, Barnyard Millet, Little Millet). Buckwheat and amaranthus are classified as pseudo cereals because they have a high concentration of carbs, comparable to that of cereals. Millet-based food items have attracted interest due to their low Glycemic Index and anti-diabetic properties. These products have the potential to provide health advantages such as lowering postprandial blood glucose levels and glycosylated haemoglobin. It is crucial to prioritize the incorporation of traditional, nutrient-rich, and low-glucose staple foods in the diets of people in poor countries to

effectively manage and prevent diabetes. Millets and sorghum are particularly recommended for this purpose. India is the leading global producer of millet. According to the 2020 reports (Dayakar et al., 2017). India is the top producer of pearl millet (Bajra) worldwide, contributing to 40% of the global output. The primary Indian states that cultivate millets include Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, Gujarat, Madhya Pradesh, Tamil Nadu, Andhra Pradesh, and Uttarakhand. Between 2020 and 2021, these eleven states in India together account for more than 98% of the millets produced. Six states, namely Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, Haryana, and Gujarat, account for almost 83% of global millet production. Rajasthan accounts for 28% of India's millet production (Thathola et al., 2011), (Itagi et al., 2012). Given the diverse range of studies on millets and their effects on glycemic control, it's crucial to compile scientific evidence to determine whether millets, in various forms including different processing methods, support glycemic control. This comprehensive review aims to analyze all relevant research on millet-based diets, covering factors like glycemic index, blood glucose levels, insulin response, and HbA1c biomarker levels (Selvin et al., 2004) . By including data from studies on 11 types of millets, one mixed millet, and various processing methods, this review will provide a solid foundation for understanding the relationship between millets and diabetes (Vetriventhan et al., 2020). The findings will not only benefit the scientific community but also inform dieticians, nutritionists, food processors, and policymakers in shaping health, nutrition, and agricultural initiatives.

1.2 TYPES OF MILLETS

Millets are categorised into two types:

1. Major Millets
2. Minor Millets

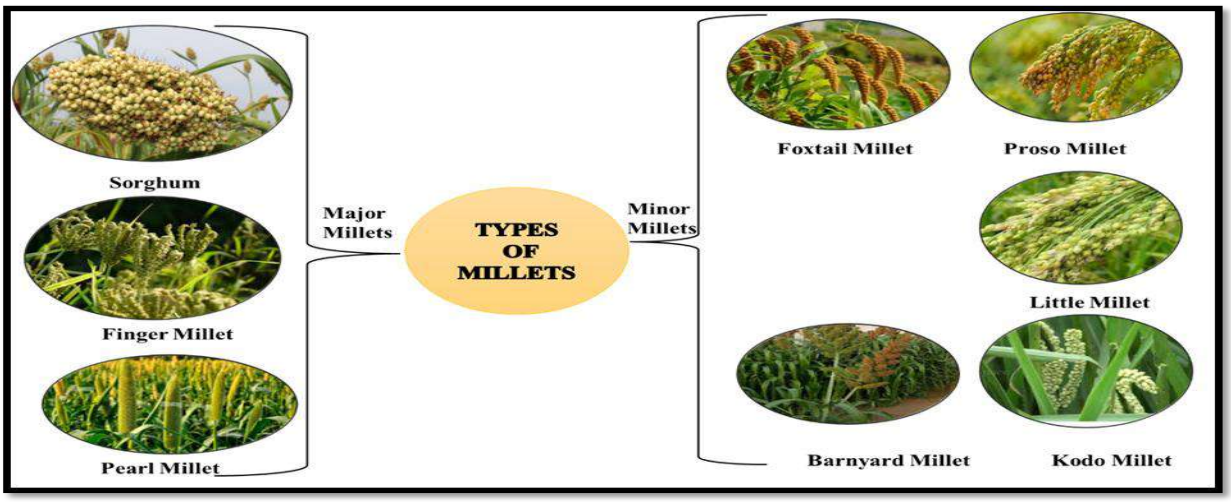

Figure No. 1: Showing the different types of Millets.

1.2.1 MAJOR MILLETS

1.2.1.1 Sorghum:

Scientifically, Sorghum is identified as Sorghum bicolour L., and it has considerable cultural, nutritional, and agronomic significance in many regions of the globe. Sorghum is thought to have originated in Africa, although it is cultivated globally, especially in India. India is a significant hub of sorghum variety because it has a wide range of landraces and cultivars that are well-suited to various agro-climatic conditions. Sorghum is well-suited for semi-arid and dry locations with low water supply, making it an adaptable crop for areas where irrigation is sparse or unreliable. The crop's drought resilience and capacity to flourish in challenging environments make it very important for small-scale farmers in developing nations, therefore enhancing food security and livelihoods. Sorghum contains carbohydrates, which makes it an important source of energy in diets. Additionally, it serves as a valuable provider of nutritional fiber and protein, which aids in promoting digestive well-being. In addition, sorghum is rich in vital minerals like iron and magnesium, along with several vitamins and antioxidants. Thus, Sorghum is often known as the "King of Millets"(Mawouma et al., 2022).

1.2.1.2 Botanical Description Habit: Sorghum is a tall, annual plant that is monoecious, meaning it has distinct male and female flowers on the same plant. It often has one to many tillers sprouting from the base or nodes of the stem. Sorghum has a chromosomal number of 20, with each cell containing two sets of chromosomes. The sorghum stem is robust and often linear. The majority of sorghum roots are located around the surface of the soil, however they may extend up to twice that depth and spread horizontally. The leaves of sorghum are simple,

arranged in an alternating pattern, and possess a lengthy leaf sheath that often has a waxy appearance. Their base near attachment is adorned with a ring of little white hairs and they are capable of articulation. The blades have a short length and have a shape that is either lanceolate or linear lanceolate. At first, they stand upright before bending, exhibiting either flat or undulating edges. The fruit of sorghum is a caryopsis, which is a kind of grain that contains an embryo. The object is globular in shape and has a rounded tip, with some of its surface covered with glumes (Harinarayanan et al., 2023).

Table 1: Showing the family Description of Sorghum

Sr. No.	**Description**		**Reference**
1.	**Botanical name**	*Sorghum bicolor (L.)*	(Harinarayanan et al., 2023)
2.	**Family**	*Sorghum bicolor (L.)*	
3.	**Common name**	**Malayalam** :Manicholam, **Tamil** : Cholam, **Kannada** : Jola, **Telugu** : Jonna **Hindi** : Jowar	

1.2.2.1 Pearl millet:

Pearl Millet, also known as bajra, is widely cultivated throughout India in both irrigated and rain-fed areas. The quick growth rate of this plant makes it very desirable for farmers, particularly in areas where water is scarce. Bajra is a very nutritious grain that provides a substantial amount of energy and is rich in proteins, minerals, and vitamins. Additionally, it offers a substantial quantity of nutritional fiber (Thathola et al., 2011) .

Table 2: Showing the family Description of Pearl millet.

Sr. No.	**Description**	**Reference**

1.	**Botanical name**	Cenchrus americanus (L.) Morrone	(Harinarayanan et al., 2023), (Chaudhary et al., 2020)
	Synonym	Pennisetum glaucum (L.) R.Br.	
2.	**Family**	Poaceae	
3.	**Common name**	Pearl Millet Malayalam :Kambam Tamil : Kambu Kannada : Sajjai Telugu : Sajjalu Hindi : Bajra Fig. 1- C & D Habit and Grains of Major Millets in India. Eleusine coracana (L.) Gaertn.	

1.2.2.2 Botanical Description Habit: Herb that grows annually; **Root**: There is a very extensive root system; **Stem**: The stem is sturdy, slender, and has a base diameter of 1-3 cm. It has noticeable nodes that can be either glabrous or hairy. **Leaf**: Usually glabrous, leaf-sheaths are open above and overlap at the base. The leaf blade is lanceolate up to 1.5 m x 5-8 cm and is linear to linear; **Inflorescence**: The inflorescence is a terminal panicle that is 5-150 cm long, cylindrical, compact, and rigid like a spike; **Seed**: The colours of seeds are white, yellow, blue-white, light grey or brown, and sometimes purple; Number of chromosomes: 2n=14.

1.2.3.1 Finger millet:

Finger millet grains are rich in proteins, dietary fiber, minerals, and polyphenols. Finger millet, rich in calcium, is advantageous for the growth and development of children, pregnant women, and those with diabetes, obesity, and malnutrition. The high potassium level of the food promotes the proper functioning of the kidneys, brain, muscles, and nerves (Chandra et al., 2016).

Table 3: Showing the family Description of Finger millet.

Sr. No.	**Description**		**Reference**
1.	**Botanical name**	Eleusine coracana (L.) Gaertn.	(Harinarayanan et al., 2023)
2.	**Family**	Poaceae	

3.	**Common name**	Finger millet Malayalam : Ragi, Muthaari Tamil : Kelvaragu Kannada : Ragi Telugu : Ragulu Hindi : Mandua Another significant staple grain in Eastern Africa and Asia is finger millet, often known as Ragi in India	

1.2.3.2 Botanical Description Habit: The plant is an annual herb that grows upright. The stem is straight and rises vertically. The root system is very strong and fibrous. The leaves have a linear shape with a flattened leaf sheath. They are often folded with a prominent midrib and can be either smooth or sparsely hairy. The inflorescence consists of a straight or slightly curved whorl of two to eight digitate leaves. The androecium has three stamens with anthers that are 1-1.5 mm long. The gynoecium has basal placentation. The fruit is a caryopsis. The plant has a chromosome count of 2n=36 (Harinarayanan et al., 2023).

1.3 MINOR MILLETS

1.3.1 Foxtail millet:

Foxtail millet is a resilient crop that can flourish in desert and unfavourable conditions with high temperatures. Due to its rapid growth rate, this plant can achieve its maximum growth potential with less than 12 hours of sunshine. It has a substantial amount of carbohydrates, which assists in regulating the body's blood sugar levels. The iron content is high. Furthermore, foxtail millet has the potential to enhance both malnourishment and overall immunity. The high potassium concentration in it promotes optimal kidney and brain function, as well as the efficient functioning of muscles and the brain (Geetha et al., 2020).

Sr. No.	**Description**		**Reference**
1.	**Botanical name**	Poaceae	(Harinarayanan et al., 2023)
2.	**Family**	Setaria italica (L.) P. Beauv.	

3.	**Common name**	Millet foxtail Thina in Malayalam Thenai in Tamil Navane in Kannada Korralu in Telugu Hindi: Kakum, Kangni	

Table 4: Showing the family Description of Foxtail millet.

1.3.1.1 Botanical characterization: Customary; perennial turf the stem is typically smooth, clustered, upright, and has sections called nodes and internodes. Leaf: The leaves typically lack hair and have lanceolate and serrated blades that alternate, measuring 15–50 cm in length and 0.5–4 cm in width; The inflorescence is a panicle that is erect or pendulous, resembling a spike and covered in bristles. It is 5-30 cm in length and 1-5 cm in breadth, and contains six to twelve spikelets. The seeds, with a diameter of about 2 mm, are enveloped in a delicate shell that may be easily separated during threshing. The color of seeds exhibits substantial variation across different varieties; Chromosome count: diploid number of chromosomes is 18 (2n=18).

1.3.1.2 Proso millet:

Proso millet is high in proteins, vitamins, minerals, dietary fibre, and polyphenols. Because it is gluten-free, it is perfect for those who are intolerant to gluten. The presence of abundant lecithin in proso millet contributes to the optimal functioning of the neurological health system. The substance contains a plentiful amount of minerals such as phosphorus, calcium, zinc, and iron, as

well as vitamins like niacin, B-complex vitamins, and folic acid. Additionally, it contains significant amounts of vital amino acids like methionine and cysteine (Itagi et al., 2012) .

Table 5: Showing the family Description of Proso millet.

Sr. No.	Description		Reference
1.	**Botanical name**	Panicum miliaceum L	(Harinarayanan et al., 2023)
2.	**Family**	Poaceae	
3.	**Common name**	Proso Millet Kannada: Baragu; Malayalam: Varagu; Tamil: PanivaraguVaragalu in Telugu Hindi: Barr	

1.3.1.3 Botanical description: Refers to a detailed and scientific account of the physical characteristics and features of a plant species. Habit: This plant is an annual herbaceous grass. Root: Consists of a fibrous root structure; stem: The culm has cylindrical, hollow, and glabrous internodes. The leaf is composed of two parts: the leaf sheath and the leaf blade. The blades have a linear lanceolate shape. Inflorescence: A cluster of little flowers arranged in a panicle or spikelet. Flower arrangement: Spikelets mostly located at the distal ends of branches; Corolla: Lacking petal; the length of the anther in the androecium is between 1.7 and 2.1 mm. Gynoecium: ovary positioned above other floral parts; Type of fruit: Caryopsis; The chromosome number is 2n=36.

1.3.1.4 Kodo millet:

Kodo millet, often referred to as Kodon millet, is a kind of millet that is easily digested and has elevated levels of the amino acid lecithin. It has a substantial impact on enhancing the neurological system. Kodo is an excellent provider of B vitamins, including niacin, B6, and folic acid, along with other essential vitamins and minerals. It is rich in calcium, iron, potassium, magnesium, and zinc minerals. As millet that is devoid of gluten, it is very suitable for persons

who are sensitive to gluten. Regular use of this food by post-menopausal women helps alleviate cardiovascular diseases, including hypertension and elevated cholesterol levels (Sobhana et al., 2020).

Table 6: Showing the family Description of Kodo millet.

Sr. No.	Description		Reference
1.	**Botanical name**	Paspalum scrobiculatum L.	(Harinarayanan et al., 2023)
2.	**Family**	Poaceae	
3.	**Common name**	Creeping paspalum Malayalam : Koovaragu Tamil : Varagu Kannada : Harka Telugu : Arikelu Hindi : Kodon	

1.3.1.5 Botanical characterization Characteristic: The plant may be either an annual or perennial grass; Root: The plant has a fibrous root system that grows from the lowest node. Stem: Culms are tufted, upright, and sometimes prostrate; the leaf is a basic structure that is arranged singly, without a stalk, and consists of a leaf sheath and a leaf blade. The leaf blades are linear, lanceolate, or linear in shape. The inflorescence consists of two racemes, which are either digitate or carried on an axis that may reach a length of up to 8 cm. Fruit: Caryopsis; The chromosome number is 2n=40 (Chaudhary et al., 2020).

1.3.1.6 Barnyard millet:

Barnyard millet is popular in millets name list and also known as Sanwa. It is a very nutritious food, rich in protein, carbohydrates, fiber, and particularly higher in micronutrients such as iron and zinc compared to other main cereals. Although barnyard millet has significant nutritional and agronomic advantages, it has not been widely employed as a crop. In recent decades, there have been little efforts to investigate the characteristics of this crop. This product contains a significant number of dietary fibers, which may effectively enhance bowel movement and facilitate weight reduction. It has high levels of calcium and phosphorus, which helps enhance bone density. Barnyards are often used for human consumption and as fodder for animals (Narayanan et al., 2016).

Table 7: Showing the family Description of Barnyard millet.

Sr. No.	Description		Reference
1.	**Botanical name**	Echinochloa crus-galli (L.) P.Beauv.	(Harinarayanan et al., 2023)
2.	**Family**	Poaceae	
3.	**Common name**	Barnyard Millet Malayalam : Kuthiravaali Tamil : Kuthiravaali Kannada : Oodalu Telugu : Udalu, Kodisama Hindi : Sanwa	

1.3.1.7 Botanical characterization Characteristics: This plant is an annual grass that grows habitually. The stem of the plant is strong and dense, growing upright or lying down, frequently producing roots and branches at the nodes, located close to the plant's base. The leaves, which are 1.5cm broad, often have gently undulating margins. The inflorescence is upright and extends beyond the final leaves. It is green or tinted with purple and is 5 to 50cm in length. The lack of ligule and the abundance of inflorescences that are either spreading, ascending, or branching; The seedheads are a panicle located at the uppermost part, measuring between 4 and 16 inches in length. Panicles may vary in color from green to purple and consist of individual spikelets that may have a terminal awn measuring 2-10 mm in length. The chromosome number is 54, with a diploid number of 2n (Chaudhary et al., 2020).

1.3.1.8 Little millet:

Little millet is grown throughout India and is a traditional crop. Little millet is a kind of Proso millet, with much smaller seeds. It is sometimes referred to as Moraiyo, Kutki, Shavan, and Sama. It has a high concentration of vitamin B and vital minerals like Calcium, Iron, Zinc, and Potassium. Little millet is extensively used in the Southern regions of India for a wide range of traditional culinary preparations. It is a more nutritious substitute for rice and does not contribute to weight gain (Dayakar et al., 2017).

Sr. No.	Description	Reference

1.	**Botanical name**	Paniculamsumatrense Roth	(Harinarayanan et al., 2023)
2.	**Family**	Poaceae	
3.	**Common name**	Little Millet Malayalam : Chaama Tamil : Samai Kannada : Same Telugu : Samalu Hindi : Kutki	

Table 8: Showing the family

Description of Little millet.

1.3.1.8 Botanical Description Habit: Annuals or perennials; Stem: culms 20-60 cm high; nodes glabrous; Leaf: Leaves 30 x 1.5 cm, linear-lanceolate, base rounded, glabrous; ligule a fimbriate membrane; Panicle to 30 cm long, contracted. Spikelets 3 x 1.5 mm, ellipsoid; lower glume 1 x 1.5 mm, broadly ovate, 3-nerved; upper glume 2.5 x 1.5 mm, ovate, 13-nerved; lower floret empty; first lemma similar to upper glume; palea hyaline; second lemma 2 x 1 mm, ovate, coriaceous; palea 2 x 1 mm, coriaceous, margins folded; stamens 3; Fruit: Caryopsis; Chromosome number: 2n=36 (Harinarayanan et al., 2023).

1.4 STRUCTURE OF MILLET GRAIN AND DISTRIBUTION OF BIOACTIVES:

As previously mentioned, there are several types of millet throughout the world, but they all have essentially the same basic grain structure. Like other grains, millet is made up of a germ, an endosperm, and a pericarp (Schematic diagram is shown in Fig.1). The outermost coat that envelops the seed's endosperm and germ is known as the pericarp. The aleurone layer and starchy endosperm make up the endosperm. The majority of the grain is made up of the starchy

endosperm, which has both floury and horny sections. The starchy endosperm is encased in an aleurone layer that is composed of protein, lipids, vitamins, and minerals. The embryo and scutellum are parts of the grain germ, which is high in lipids, proteins, and minerals. When compared to other grains, the millet germ is somewhat larger (Akanbi et al., 2019).

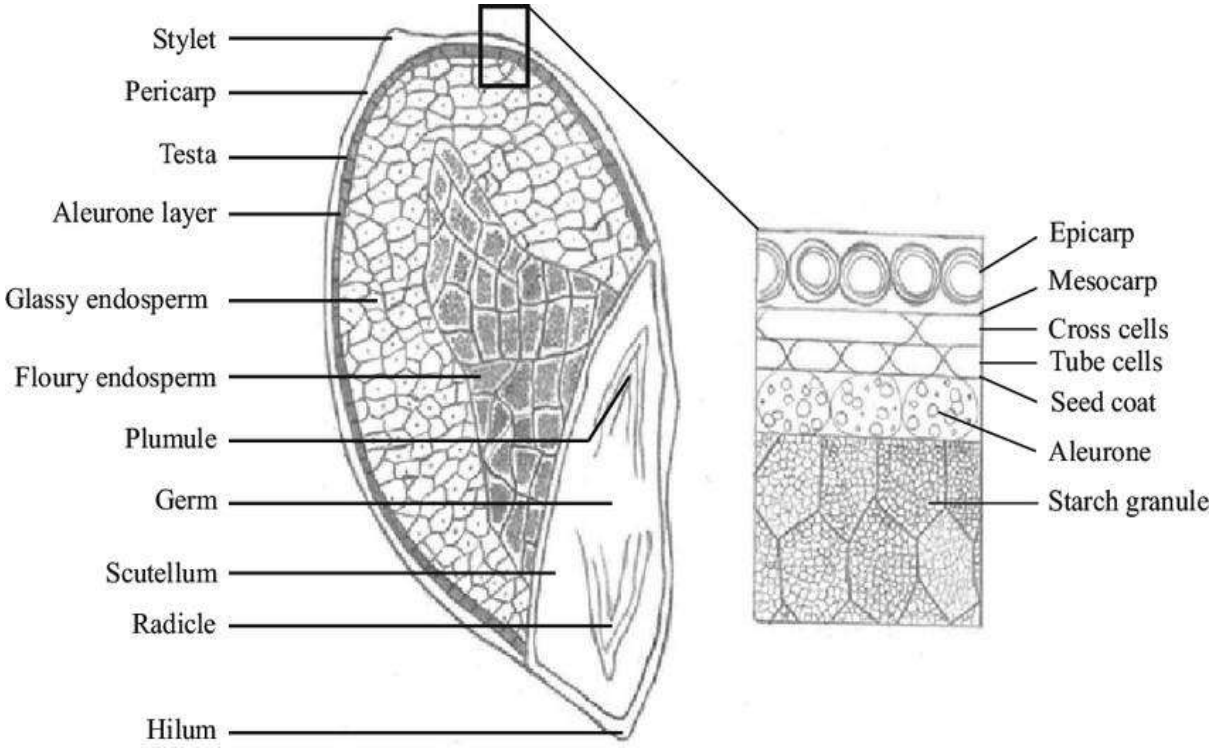

Figure No. 2: Schematic diagram showing the structure of millet grain. The figure concept is based on the detailed structure of the grain reported by Mcdonough and Rooney (Mcdonough & Rooney, 1989).

Consequently, there is less starchy endosperm. In proso millet, for instance, endosperm makes up 70% of the grain's weight, yet in sorghum, a close related, endosperm makes up more than 80%. Further reports exist regarding the detailed structural properties of millet and other cereal grains (Evers & Millar, 2002), (Mcdonough & Rooney, 1989). It is important to remember that fine structure varies greatly among types, including pericarp thickness and the ratio of germ to endosperm. It is commonly known that millet's seed coat contains the majority of the plant's bioactive components. The endosperm mostly consists of starchy material and has very little bioactive material (Chethan & Malleshi, 2007).

2 BIO ACTIVE PHYTOCONSTITUENTS OF MILLETS:

Millet grains hold a good quantity of bio-active compounds that involve polyphenols- (vanillic acid, sinapic acid, coumaric acid), Flavonoids- (quercetin, luteolin, catechin, myricetin), tannins, photo- sterols. These components possess numerous health benefits for sustaining a healthy life (Akanbi et al., 2019).

Pharmacological Properties of Millets

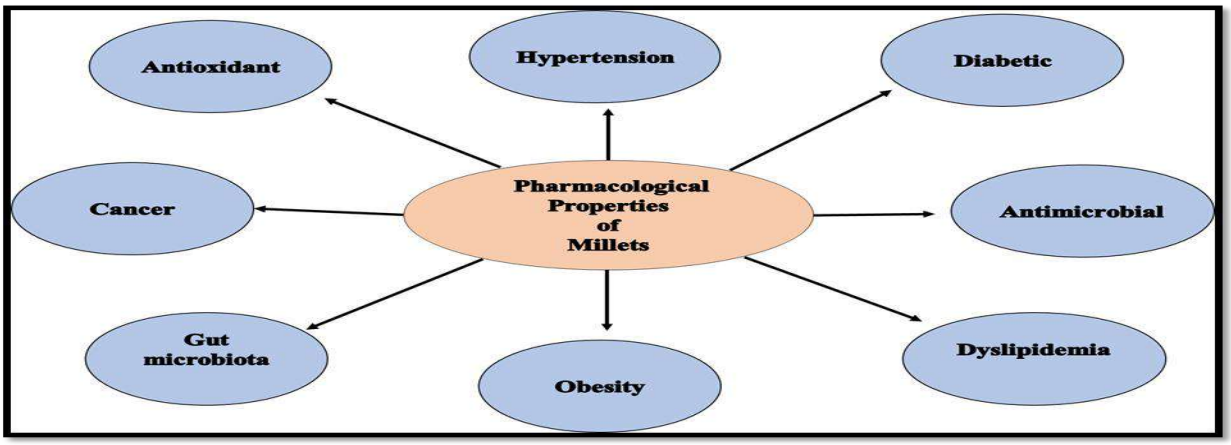

Figure No. 2: Showing the Pharmacological properties of Millets.

2.1 Antioxidants:

The polyphenols included in tiny finger millets exhibit antioxidant action by decreasing DPPH and converting ferrous ions to ferric ions. When alloxan-induced diabetic rats were fed a baseline diet, more than 50% of the diet consisted of finger millet and kodo millets. This feeding was done for a period of 28 days. The study found that the millets diets had a substantial impact on oxidative stress and glucose levels in the rats. Finger and pearl millet exhibit significant antioxidant activity by effectively employing the 2, 2-diphenyl-1-1-picrylhydrazyl (DPPH) radical scavenging capability. Several samples of flour made from foxtail millet have been shown to possess antioxidant properties, as indicated by their high levels of total phenolic and flavonoid content. The specific values for these compounds are as follows: total 5.2 Sorghum 10.4-10.82 70.7-72.9 1.9-3.1 1.6-2.0 329-349 11309 Eur. Chem. Bull. 2023,12(10), 11306-11313 Antioxidant capacity, ferric reducing antioxidant power (FRAP) test, and 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity are methods used to measure the ability of a substance to prevent oxidation and neutralize free radicals.

2.2 Cancer:

Foxtail millets contain a unique 35 kDa protein called FMBP. In vivo, the anticancer FMBP has the capacity to inhibit the development of xenografted tumors in mice and is used as an anti-colon cancer agent. In the BALB/c mice model, foxtail millets shown a substantial reduction in AOM/DSS-induced colitis linked colorectal cancer. Vanillin, an active chemical derived from Proso and barnyard millets, has been shown to suppress cell growth and induce apoptosis in the HT-29 cell line of colon cancer. The drug sensitivity of Colorectal cancer cells to oxaliplatin is enhanced by a specific polyphenol isolated from foxtail millet bran. This enhancement is achieved by the remodelling of NEU3-mediated ganglioside GM3 catabolism, known as OXA13. The extraction of bound polyphenol from foxtail millet bran shown the ability to suppress the growth of cancer cells. This effect was seen in the presence of ferulic acid (FA) and p-coumaric acid (p-CA). The soluble dietary Fiber derived from foxtail millets has the potential to hinder the ability of HT-29 cells and HCT116 cells to form colonies. Additionally, it may substantially enhance the production of reactive oxygen species (ROS) and induce apoptosis in HT-29 cells and HCT116 cells.

2.3 Obesity:

LACA mice on a high-fat diet were administered whole grain and bran of finger millet for duration of 12 weeks. The bran of finger millet is very efficient in reducing obesity, improving lipid profile, and regulating the expression of genes associated to obesity.

2.4 Dyslipidaemia:

Male infant at 40 weeks of age Sprague rats are subjected to an eight-week period of consuming a diet heavy in fat to produce hyperlipidemia. They are then separated into four groups and provided with different types of grains (white rice, sorghum, foxtail millet, and proso millet) for a duration of five weeks. Foxtail millets and proso millets had a lower concentration of blood triglycerides, whereas sorghum groupings have greater levels of serum total HDL and LDL. The powder derived from the whole pearl millet grain and its ethanol extract have a dose-dependent effect in reducing obesity, lowering blood sugar levels, decreasing lipid levels, reducing inflammation, and preventing fat accumulation in obese rats fed high-fat diets. The Proso millet-based diet is given to rats that are on a high-fat diet (HFD), and it has positive effects on the levels of plasma HDL, LDL, total cholesterol, and triglycerides. The inclusion of whole flour and hydroalcoholic extract of finger millet (Elusine coracana) has been shown to have a major impact in reducing body weight, BMI, fasting blood sugar levels, and improving the lipid profile in mice

fed a high-fat diet18. The hydroalcoholic extract of finger millet seeds (Elusine coracana) demonstrated superior efficacy at a high dosage compared to the whole flour.

2.5 Diabetic:

A high intake of foxtail millet-based diet is given to 300 Diabetes type 2 patients and are very effective to manage diet HbA1c , fasting glucose , insulin concentrations, total cholesterol concentrations , triglyceride concentrations , and LDL.

2.6 Gut Microbiota:

Intestinal microorganisms A streptozotocin (STZ)-induced model of type 2 diabetes (T2DM) is administered purified millet bran polysaccharide at three distinct dosages (400 mg/kg, 200 mg/kg, and 100 mg/kg) in combination with a high-fat diet. Following a four-month therapy, the millet bran polysaccharide group had an improvement in blood lipid levels. Additionally, this treatment led to a rise in helpful bacteria and a reduction in dangerous bacteria in the digestive tract of rats. The binding of polyphenols from the inner shell of foxtail millets bran has been shown to enhance the presence of commensal bacteria such as Lachnospiraceae and Rikenellaceae in mice with experimental colitis produced by dextran sodium sulfate (DSS).

3.PRODUCTION OF MILLETS:

3.1 World production of millet:

By 2045, the global diabetic population is projected to rise by 51%, reaching 700 million individuals, compared to 463 million in 2019 (IDF, 2021). Type 2 diabetes is expected to make up around 90% of these cases. Low- and middle-income countries, where 87% of diabetes-related fatalities occur, have a limited range of staple food consumption. It is crucial to bear in mind that, apart from obesity and a sedentary lifestyle, food intake has a significant role in the development of diabetes. Refined wheat, refined rice, and maize are the primary sources of sustenance in developing nations, constituting over 80% of overall energy intake (Anitha et al., 2019). In addition, millets possess antibacterial and antioxidant properties. The protein content of tiny millet is 7.7%, Kodo millet is 8.3%, Proso millet is 11%, Pearl millet is 14.5%, and Foxtail millet is 11.7%, which is greater than the protein content of rice, which is 7.5%. Furthermore, millets often possess elevated concentrations of total phenol and dietary fibre compared to cereals (Chandra et al., 2016). Millets serve as a crucial source of sustenance for many individuals worldwide, particularly those residing in arid and warm regions. The global availability of millets encompasses thirteen distinct varieties (Amadou et al., 2013), including

sorghum, small millet, finger millet, pearl millet, proso millet, kodo millet, barnyard millet, brown top millet, foxtail millet, Guinea millet, Job's tears, fonio, and teff. Except for teff, fonio, and Job's tears, all other types of millets are readily accessible in India. Job's tears are distributed in northeast India, southern and eastern Asia, and southern China, whereas finger millet is widely spread in India, China, and many Eastern and Southern African nations. Nevertheless, Ethiopia is home to the largest portion of teff (Vetriventhan et al., 2020). Currently, the United States, being the largest producer of sorghum, is accompanied by Africa and Asia in the production of these crops. Millets are cultivated as a minor crop or for use as feed and fodder in many locations of the globe, as stated in www.smartfood.org/millets-sorghum-production-trends/. Promoting smart foods is crucial, since they fulfill all the necessary criteria for being healthy for individuals, the environment, and farmers. This is particularly important considering the nutritional needs, the increasing prevalence of non-communicable health issues such as diabetes, and the difficulties posed by climate change. Millets have shown efficacy in reducing fasting blood glucose levels, improving insulin sensitivity, reducing the increase in blood glucose concentration after fasting and meals, and lowering the level of glycosylated hemoglobin (HbA1c) [6-10]. The Glycaemic Index (GI) measures the extent to which the carbohydrate content of a meal affects the speed and extent of increases in blood glucose levels after eating. Consuming low-glycemic index (GI) foods is the established dietary method for enhancing glycemiccontrol (Narayanan et al., 2016).

3.2 India millets production:

The total area of millets considered from 1970-1971 to 2018-2019 showed a consistent decline. The area dedicated to cultivating pearl millet has shrunk by around 34% due to a significant 2.5-fold gain in productivity. However, this increase in productivity has resulted in a remarkable 63% rise in output. The cultivation area of Jowar, which accounted for a significant portion in the 1970s (16.55 Mha), decreased to 6.04 Mha, resulting in a reduction of about 64 percent. This decline in cultivation area led to a 44 percent decrease in output, despite a 51 percent increase in productivity. The Ragi cultivation area has seen a reduction of almost 50%, leading to a consequent decline in output of around 23%, despite a simultaneous gain in productivity of 68%. Small millets had the most significant decrease in area, with a loss of 85%, resulting in a 77% decrease in output, despite a 58% rise in yield over the research period. Thus, it can be deduced that the rise in millets output has not compensated for the decrease in their cultivation area, save for pearl millet.

4. CONCLUSION:

Millets are superior to main cereals like rice and wheat because they contain a variety of minerals, protein, vitamins, and phytochemical active components. Millets have been shown to be quite beneficial in treating a number of diseases, including cancer, diabetes, and hypercholesterolemia. Millets should be eaten on a regular basis to maintain good health and fend off many illnesses, particularly those related to lifestyle choices.

5. DECLARATIONS

5.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

5.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

5.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

6. REFERENCES

1. International Diabetes Federation. Global Diabetes Data Report 2010–2045. Available online at: diabetesatlas.org.
2. Anitha S, Kane-Potaka J, Tsusaka TW, Tripathi D, Upadhyay S, Kavishwar A, et al. Acceptance and impact of millet-based mid-day meal on the nutritional status of adolescent school going children in a peri urban region of Karnataka State in India. Nutrients. (2019) 11:2077. doi: 10.3390/nu11092077.
3. Chandra D, Chandra S, Pallavi, Sharma AK. Review of Finger millet (Eleusine coracana (L.) Gaertn): A power house of health benefiting nutrients. Food Science and Human Wellness. 2016; 5:149-155.
4. Amadou I, Gounga ME, Le GW. Millets: Nutritional composition, some health benefits and processing-A review. Emirates Journal of Food and Agriculture, 2013, 501-508.
5. Vetriventhan M, Vania C, Azevedo R, Upadhyaya HD, Nirmalakumari A, Kane-Potaka J, et al. Genetic and genomic resources, and breeding for accelerating improvement of small

millets: current status and future interventions. Nucleus. (2020) 63:217–39. doi: 10.1007/s13237-020-00322-3.

6. Palanisamy T, Sree R. Efficacy of millets (foxtail, kodo, small, barnyard and pearl millet) varieties on post prandial glycaemic response in patients with type 2 diabetes. Eur J Biomedpharm Sci. (2020) 7:443–9. 9.

7. Thathola A, Srivastava S, Singh G. Effect of foxtail millet (Setaria Italica) supplementation on serum glucose, serum lipids and glycosylated haemoglobin in type 2 diabetics. Diabet Croat. (2011) 40:23–9.

8. Itagi S, Naik R, Bharati P, Sharma P. Readymade foxtail millet mix for diabetics. Int J Sci Nat. (2012) 3:47–50.

9. Sobhana PP, Kandlakunta B, Nagaraju R, Thappatla D, Epparapalli S, Vemula SR, et al. Human clinical trial to assess the effect of consumption of multigrain Indian bread on glycaemic regulation in type diabetic participants. J Food Biochem. (2020) 44:e13465. doi: 10.1111/jfbc.13465 .

10. Geetha K, Geetha MY, Hulamani S, Hiremath N. Glycaemic index of millet based food mix and its effect on pre diabetic subjects. J Food Sci Technol. (2020) 57:2732–8. doi: 10.1007/s13197-020-04309-5.

11. Narayanan J, Sanjeevi V, Rohini U, Trueman P, Viswanathan V. Postprandial glycaemic response of foxtail millet dosa in comparison to a rice dosa in patients with type 2 diabetes. Indian J Med Res. (2016) 144:712–7. doi: 10.4103/ijmr.IJMR_551_15.

12. Dayakar RB, Bhaskarachary K, Arlene Christina GD, Sudha Devi G, Vilas AT, Tonapi A. Nutritional and health benefits of millets. ICAR Indian Institute of Millets Research (IIMR),2, Rajendranagar, Hyderabad. 2017.

13. Selvin E, Marinopoulos S, Berkenblit G, Rami T, Brancati FL, Powe NR, et al. Meta-Analysis: glycosylated hemoglobin and cardiovascular disease in diabetes mellitus. Ann Intern Med. (2004) 141:421–31. doi: 10.7326/0003-4819-141-6-200409210-00007.

14. Mawouma S, Condurache NN, Turturicã M, Constantin OE, Croitoru C, Rapeanu G. Chemical composition and antioxidant profile of Sorghum (Sorghum bicolor (L.) Moench) and pearl millet (Pennisetum glaucum (L.) R. Br.) grains cultivated in the far-North region of Cameroon. Foods.;11(14):2022. https://doi.org/10.3390/ foods11142026.

15. Harinarayanan C.M., Haritha V., Geetha S. Pillai, Indira Balachandran. A review on botanical, phytochemical, nutritional and pharmacological properties of major millets in India. ARYAVAIDYAN, 2023, pp. 41 – 49.

16. Ojo OA, Ojo AB, Barnabas M, Iyobhebhe M, Elebiyo TC, Evbuomwan IO, Michael T, Ajiboye BO, Oyinloye BE, Oloyede OI. Phytochemical properties and pharmacological activities of the genus Pennisetum: A review. Scientific African 16:e01132,2022. https://doi.org/10.1016/j.sciaf.2022.e01132.

17. C M, Harinarayanan & V, Haritha & Pillai, Geetha & Balachandran, Indira. (2023). A review on botanical, phytochemical, nutritional and pharmacological properties of major millets in India. 36. 41 - 49.

18. Sumit Chaudhary, PS Negi, Alankar Singh, R K Prasad, Pallavi, Ajay Kumar, Rajesh Kaushal. A short review on millets: A potential nutricereals. Pharma Innovation 2020;9(10):123-126.

19. Akanbi, Taiwo & Timilsena, Yakindra & Dhital, Sushil. (2019). Bioactives from Millet: Properties and Effects of Processing on Bioavailability. 10.1007/978-981-13-6167-8_10.

20. Evers T, Millar S (2002) Cereal grain structure and development: some implications for quality. J Cereal Sci 36:261–28.

21. Mcdonough CM, Rooney LW (1989) Structural characteristics of Pennisetum americanum using scanning electron and fluorescence microscopies. Food Microstruct 8:137–149.

22. Chethan S, Malleshi NG (2007) Finger millet polyphenols: characterization and their nutraceutical potential. Am J Food Technol 2:618–629

A Comparative Study of Emotional Maturity among B.Ed. Teacher-Trainees in Una District of Himachal Pradesh

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ABSTRACT

This study investigates emotional maturity among 180 B.Ed. teacher-trainees from five colleges in Una District, Himachal Pradesh, using a purposive sampling design balanced by gender (90 males, 90 females) and academic stream (90 arts, 90 science). The Emotional Maturity Scale by Singh and Bhargava (1990) was administered, and data were analyzed via independent-samples t-tests. Results revealed no significant gender differences in emotional maturity ('t' (178) = 1.58, p > .05). However, arts trainees scored significantly higher than science trainees ('t' (178) = 2.21, p < .05). Within-gender comparisons showed no significant stream differences: arts males vs. science males ('t' (88) = 0.12, p > .05) and arts females vs. science females ('t' (88) = 0.28, p > .05). Findings underscore the role of academic stream in shaping emotional maturity and suggest targeted interventions, seminars, guidance programs, competitions, and gender-specific counseling in teacher-education institutions to optimize trainees' personality development and teaching readiness.

Key Words: *Emotional Maturity, B.Ed. Teacher-Trainees, Gender Differences, Arts vs. Science Streams, Emotional Maturity Scale, Teacher Education.*

1.INTRODUCTION

The educational environment profoundly shapes an individual's personality development. Daily experiences in education broaden one's understanding of the world, influencing key personality factors such as self-concept, emotional maturity, social adaptability, attitudes, and values. Emotional maturity is a critical determinant of personality. Seoul (1951) posited that complete emotional development enhances adaptability, reduces regressive tendencies, and minimizes vulnerability. Fred McKinney described emotionally mature individuals as exhibiting heterosexuality, appreciation of others' attitudes and behaviors, a tendency to adopt, and the capacity to delay responses. Such individuals continually strive for healthy integration of feeling, thinking, and action, even if not all anxiety-arousing conditions are resolved *(Singh & Bhargava, 1990)*. Emotion is a core dimension of personal experience, encompassing eight primary innate emotions: joy, anticipation, anger, disgust, sadness, surprise, fear, and acceptance. An emotionally mature person displays emotions in appropriate degrees with reasonable control, expressing them socially desirable and guided more by intellect than impulse. Emotional development is integral to educational growth, influencing nearly all human behaviors. Emotions drive thoughts, conduct, physical and mental health, social life, character, learning, and adjustment. Like instincts, emotions are vital forces in child development. Emotions manifest in every human activity, evoking pleasure, lethargy, or pain. Psychoanalysis reveals that much human misery stems from undisciplined or misdirected emotions; a happy person has well-trained emotions. Emotional experiences trigger physiological changes, including alterations in heartbeat, pulse rate, blood pressure, digestion, glandular activity, and nervous system hyperactivity. Emotions guide inner adjustment, enabling adaptation to changing surroundings through self-awareness of desires, impulses, motives, and needs *(Crow & Crow, 1973).* A person is emotionally mature if they possess a full range of positive and negative emotions and express them appropriately in degree and timing. Emotions arise from external objects, events, or internal threats to body, pride, or self-esteem (eliciting fear, anxiety, anger, or hostility) or from need gratification or goal realization. Provocative conditions evolve with expanding abilities and interests—from direct stimuli in infancy affecting immediate well-being to broader susceptibilities in later years. Education transforms individuals into personalities, maximizing potential. Academic

achievement depends on factors like subject interest, study facilities, family background, motivation, learning style, teaching methods, and study habits. Motivation, tied to thoughts, feelings, instincts, and emotions, is pivotal. School climate, home, society, and student motivation drive goal attainment, such as improved performance or grades.

2.REVIEW OF RELATED STUDIES

Ratna (2014) investigated emotional maturity of teacher-trainees in relation to gender and educational qualification. Result showed no significant gender differences in total emotional maturity whereas postgraduate trainees displayed greater emotional maturity than undergraduate.

Sharma & Sharma (2015) studied influence of demographic variables on emotional maturity of pre-service teachers. Study concluded that no significant differences emerged by location or educational status. The study further founds that gender influences emotional maturity.

Kumar (2020) studied emotional maturity and academic achievement among students of B.Ed. The study found a positive relationship between emotional maturity and academic achievement of B.Ed. students. .

Ram (2024) examined prospective teachers' emotional maturity in relation to gender, place of residence, and institution. Results indicated no gender differences, but rural trainees scored lower in their emotional maturity. Private institutions fostered better emotional maturity. The study posits that stream indirectly affects maturity through rural-urban divides.

3.Significance of the Study

Emotional maturity underpins desirable learning, fostering a stress-free mind conducive to adjustment and progress. High emotional maturity equips individuals to withstand life's strains. A child unfit physically, emotionally, or mentally cannot achieve educationally; energy diverted to ailments leaves little for learning, causing anxiety, distorted perceptions, and a negative outlook on self, others, society, and life. Environment critically shapes personality; stimulating environments promote healthy development, while dull ones hinder it. Schools facilitate peer interactions, friendships, and social groups. Prior research on this topic is limited, necessitating further investigation. This study aids parents, teachers, educators, and B.Ed. college administrators in creating environments where

trainees feel free, make independent decisions, achieve emotional stability, and maximize potential for personality growth.

4. OBJECTIVES OF THE STUDY

Keeping view the need of the study the investigator had framed the following objectives:

1) To compare emotional maturity of male and female B.Ed. teacher-trainees.

2) To compare emotional maturity of arts and science B.Ed. teacher-trainees.

3) To compare emotional maturity of arts male and arts female B.Ed. teacher-trainees.

4) To compare emotional maturity of science male and science female B.Ed. teacher-trainees.

5. HYPOTHESES OF THE STUDY

The following research hypotheses have been designed to achieve the objectives of the study:

1) Male and female B.Ed. teacher-trainees do not differ significantly in emotional maturity.

2) Arts and science B.Ed. teacher-trainees do not differ significantly in emotional maturity.

3) Arts male and arts female B.Ed. teacher-trainees do not differ significantly in emotional maturity.

4) Science male and science female B.Ed. teacher-trainees do not differ significantly in emotional maturity.

6. RESEARCH METHOD

The study employed a descriptive survey method.

6.1 Sampling Procedure

A purposive sample of 180 B.Ed. teacher-trainees was drawn from all five B.Ed. colleges in Una District, Himachal Pradesh. The sample structure is presented in table 1.

Table 1: **Structure of the Sample**

Categories	Male	Female	Total
Arts	45	45	90
Science	45	45	90
Total	90	90	180

6.2 Tool Used for Data Collection

The Emotional Maturity Scale by Dr. Yashvir Singh & Dr. Mahesh Bhargava (1990) was administered.

6.3 Statistical Technique Used

The t-test was applied to analyze differences in mean scores.

7. Results

This section of the study highlights the analysis of data and interpretation of results.

7.1 Hypothesis 1

No significant difference exists between male and female B.Ed. teacher-trainees in emotional maturity.

Table 2: Mean Difference in Emotional Maturity Scores of Male and Female B.Ed. Teacher-Trainees

Category	N	M	S.D	S.ED	df	't'	Remarks
Male	90	85.42	13.23	2.57	178	1.58	Not Significant
Female	90	89.5	20.57				

The t-value (1.58) is less than the table value (1.97) at 0.05 level with 178 df. Thus, the hypothesis is accepted: male and female trainees do not differ significantly.

7.2 Hypothesis 2

Arts and science B.Ed. teacher-trainees differ significantly in emotional maturity.

Table 3: Mean Difference in Emotional Maturity Scores of Arts and Science B.Ed. Teacher-Trainees

Category	N	M	S.D	S.ED	df	't'	Remarks
Arts	90	95.71	24.15	3.43	178	2.21	Significant
Science	90	88.1	21.94				

**Significant at 0.05 level.*

The t-value (2.21) exceeds the table value (1.97) at 0.05 level with 178 df. Thus, the hypothesis is rejected: arts trainees' exhibit significantly higher emotional maturity than science trainees.

7.3 Hypothesis 3

No significant difference exists between arts male and science male B.Ed. teacher-trainees in emotional maturity.

Table 4: Mean Difference in Emotional Maturity Scores of Arts Male and Science Male B.Ed. Teacher-Trainees

Category	N	M	S.D	S.ED	Df	't'	Remark
Arts Male	45	85.71	22.30	4.73	88	0.12	Not Significant
Science Male	45	85.13	22.63				

The t-value (0.12) is less than the table value (1.99) at 0.05 levels with 88 df. Thus, the hypothesis is accepted.

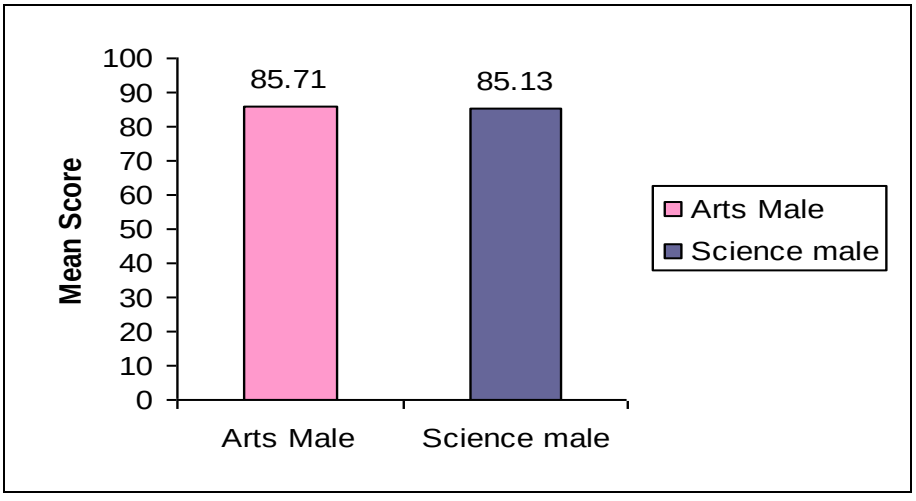

Figure No. 1: Histogram on Difference in Mean Scores on Emotional Maturity of Arts Male and Science Male B.Ed. Teacher-Trainees

7.4 Hypothesis 4

No significant difference exists between arts female and science female B.Ed. teacher-trainees in emotional maturity.

Table 5: Mean Difference in Emotional Maturity Scores of Arts Female and Science Female B.Ed. Teacher-Trainees

Category	N	M	S.D	S.ED	df	't'	Remarks
Arts Female	45	87.93	22.58	5.04	88	0.28	Not Significant
Science Female	45	89.35	25.19				

The t-value (0.28) is less than the table value (1.99) at 0.05 level with 88 df. Thus, the hypothesis is accepted.

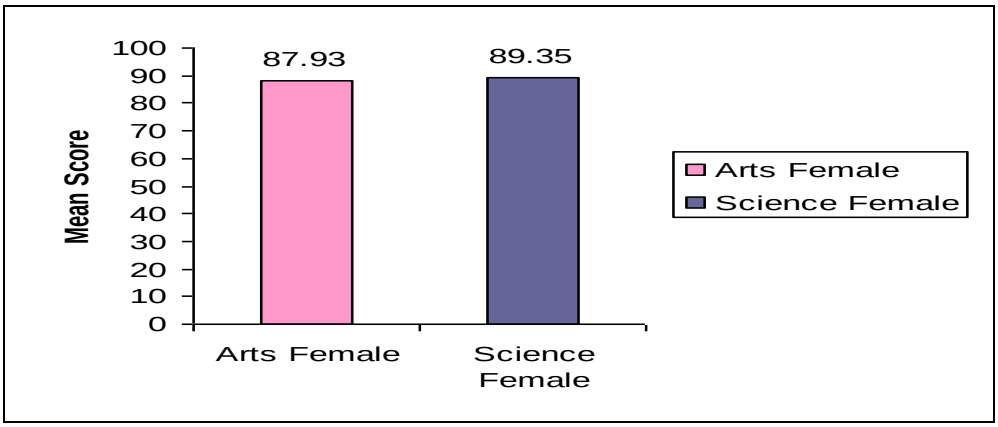

Figure No. 2: Histogram on Difference in Mean Scores of Emotional Maturity of Arts Female and Science Female B.Ed. Teacher-Trainees

7.5 MAJOR FINDINGS

On the basis of analysis of data and interpretation of results following findings were drawn:

1) Male and female B.Ed. teacher-trainees do not differ significantly in emotional maturity.

2) Arts B.Ed. teacher-trainees show significantly higher emotional maturity than science trainees.

3) Arts male and science male B.Ed. teacher-trainees do not differ significantly in emotional maturity.

4) Arts female and science female B.Ed. teacher-trainees do not differ significantly in emotional maturity.

7.6 Educational Implications

The findings of the present study have the following important implications for the educational practices:

1) Teacher educators should address stream-specific emotional maturity (arts vs. science) via targeted interventions.

2) Organize seminars on emotional maturity in B.Ed. institutes.

3) Implement guidance programs to balance trainees' emotional development.

4) Promote academic and non-academic competitions to build maturity.

5) Provide separate gender-specific guidance and counseling services.

8. CONCLUSION

The present investigation illuminates the nuanced interplay between educational environment, academic stream, and emotional maturity among B.Ed. teacher-trainees in Una District, Himachal Pradesh. With a balanced sample of 180 trainees, the study establishes that emotional maturity remains unaffected by gender—both male and female trainee's exhibit comparable levels of emotional integration, control, and socially adaptive expression. This finding challenges stereotypical assumptions and reinforces the potential of teacher-education programs to foster emotional equivalence across genders. A striking revelation, however, emerges from the academic stream comparison: arts trainees demonstrate significantly higher emotional maturity than their science counterparts. By bridging the identified stream-based gap and sustaining gender-neutral emotional development, B.Ed. colleges can transform teacher-trainees into emotionally mature professionals capable of shaping not just knowledgeable, but emotionally balanced citizens. This research, while localized, offers a scalable framework for teacher-education reform, underscoring that true educational excellence begins with the emotional wholeness of those who teach.

9. DECLARATIONS

9.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

9.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

9.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

10.REFERENCES

1. Bernard, H.W (1965). *Psychology of Learning and Teaching*. New York: Hill Book Publishing Co., 237-239.
2. Chauhan, S. S. (2007). *Advanced Educational Psychology* (7th ed.). New Delhi: Vikas Publishing House Pvt. Ltd.
3. Crow, L. D., & Crow, A. (1973). Educational psychology. New York, NY: American Book Company.
4. Garrett, Henry E. (2011). *Statistics in Psychology and Education*, New Delhi: Paragon International Publishers.
5. Good, C. V. (1973). *Dictionary of Education.* New York: Routledge Publishers.
6. Koul, Lokesh (2012). Methodology of Educational Research (4th ed.). New Delhi: Vikas Publishing House Pvt. Ltd.
7. Kumar, M., Ahmad, W., & Nazli. (2020). Emotional maturity and academic achievement among students of B.Ed. general & special education. International Journal of Indian Psychology, 8(3). https://doi.org/10.25215/0803.020
8. Ratna, K. (2014). Emotional maturity of teacher trainees in relation to gender and educational qualification. International Journal of Humanities and Social Science Research, 3(4), 201–209.
9. Seoul, P. (1951). Emotional maturity: Its nature and measurement. New York, NY: Columbia University Press.
10. Sharma, R., & Sharma, P. (2015). Influence of demographic variables on emotional maturity of pre-service teachers. Educational Quest: An International Journal of Education and Applied Social Sciences, 6(3), 177–183.
11. Singh, Y., & Bhargava, M. (1990). Emotional maturity scale manual. Agra, India: National Psychological Corporation.

Impact of Bird Flu on the Poultry Industry and the Global Economy

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ABSTRACT

"Bird flu" also known as avian influenza known for the infectious disease of birds that are caused by viruses that too commonly infect many types of wild birds as well as poultry. This virus may also infect a diversity of mammals, including human. Avian influenza virus is a zoonotic pathogen with a natural reservoir entirely in birds. In poultry industries it causes a range of disease symptoms from a subclinical infection to being highly virulent with 100% mortality. It generally spread by mean of inhalation or ingestion in natural environment. The H5N1 virus transfer zoonotically from infected poultry to humans, frequently with fatal result. Even though the virus replicates proficiently in diseased human, however it does not able to transfer efficiently in human to human. Bird flu is caused by some H5 and H7 subtypes of type A influenza virus that belongs to family Orthomyxoviridae. Mostly the bird flu viral strains are mildly pathogenic so can generate subclinical infections, respiratory infections and reproductive diseases in different wild and domestic birds species. Influenza A virus contained eight segmented, single stranded RNA viruses. Bird flu periodically causes epidemics nearly every year that leads to serious human sickness and mortality. Yet, influenza A virus is only associated with pandemic influenza virus that spread globally fast in an immunologically close population. Avian influenza virus subtypes are distinguished by antigens like haemagglutinin and neuraminidase

that are present on the surface of virus. A particular antigen combination is used to identify viral subtype like as H5N1 or H3N2. Bird flu viruses are classified as low pathogenic or highly pathogenic depending on their virulence. In developing countries the poultry farmers of poor households have found the greatest frighten of the incident of this disease.

***Keywords**: - Orthomyxoviridae, Avian influenza, H5N1, RNA virus, Bird flu.*

1. INTRODUCTION

The fast spread of this infectious disease greatly affects poultry production. Rapid and readily expanding diseases threatening poultry raised under production systems comprise avian influenza, marek's disease, infectious bursal disease, and much other respiratory disease. So, the existence of profuse virulent strains of infectious agents make poultry farming a hazardous business and thus also affect the development and economy of the country (Attia, et al., 2022). "Bird flu" or avian influenza (AI) referred as infectious disease of birds that is generated by viruses which much normally infect poultry as well as numerous kinds of wild birds. This virus also infect a great variation of mammals including humans. Globally increasing population not only driving up our demand for food, yet also the quantity of protein expected to feed all of mankind (Nadathur et al., 2017). Considerably, the earth's population is requisite to increase over 9 billion by 2050, so the requirement for poultry also increases because poultry is comparatively good, healthy and potential source of protein (Kleyn et al., 2021). To achieve this level of production it requires intension of poultry operation and also this will explain into large poultry houses When it comes about infectious disease, it is necessary to negotiate strictly that when and from where infection is getting on poultry industries therefore practice to prevent additional infection can be taken earlier. This types of practices not only help to enhance productivity of poultry but also prerequisite to human safety point of matter (Nkukwana et al., 2018).Moreover, other poultry pathogens like as *Salmonella, Campylobacter* and *Escherichia coli* are competent to induce human disease (Mor-Mur et al., 2010). Now a days the coincidence of emerged disease in human and livestock is increasing, the primary reason for these emerged disease is increased connection between livestock, human and wild animal species (Bengis, et al., 2004). Bird flu is one of the most terrifying asymptomatic infectious disease that is caused by H1N1 viruses belong to the family Orthomyxoviridae. Influenza virus genus contained negative

–sense eight segmented single –stranded Ribonucleic Acid (RNA) genome (Greger, 2007). Basically there are three kinds of influenza viruses named as influenza virus A, B, and C. influenza virus A affects mostly the warm blooded mammals and domestic animals like as poultry, horses, and pigs, etc (Dangi et al., 2012 & Gholizadeh et al, 2023). These viruses most commonly infect poultry as well as many types of wild birds. Some Avian Influenza viruses are also known to infect a variety of mammals, including humans. AI virus subtypes are distinguished by the haemagglutinin and neuraminidase antigens (glycoproteins) (Perdue et al., 2000) that cover the virus surface as shown in fig. 1

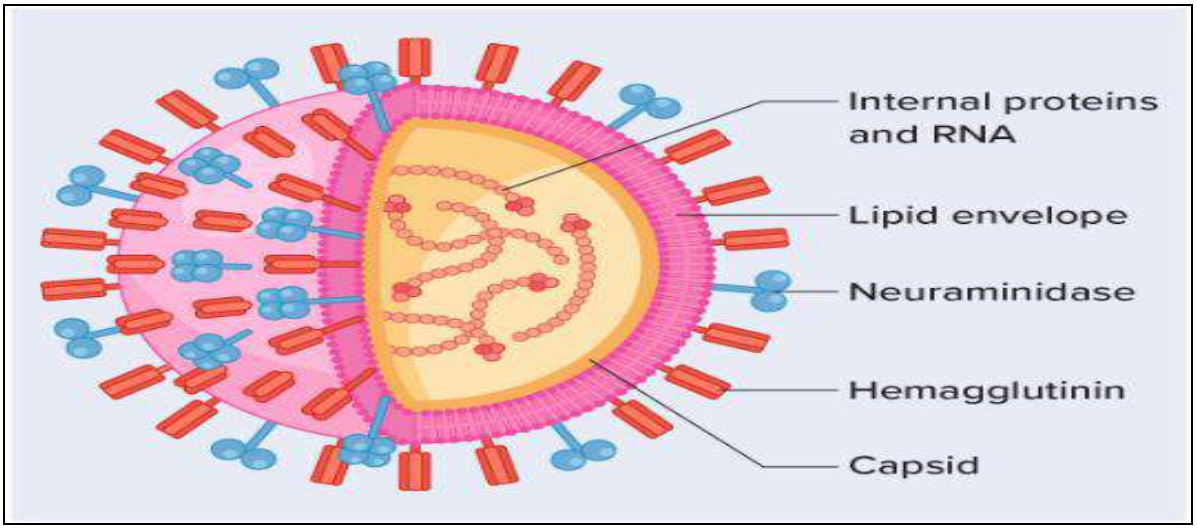

Figure No .1: Structure of Avian influenza virus (source: adapted from knowablemagazine.org) (**Source:**https://knowablemagazine.org/content/article/health-disease/2025/scientific-facts-about-h5n1-bird-flu)

All 16 haemagglutinin and nine neuraminidase antigens have been identified in wild bird populations (Russell et al., 2011). At least 16 hemagglutinins (H1 to H16), and 9 neuraminidases (N1 to N9) have been found in viruses from birds, while two additional HA and NA types have been identified only in bats (Ciminski et al., 2021). The viruses are roughly spherical (120 n M) with glycoprotein spikes on the surface and genome consisting of also eight RNA fragments that encode 10 proteins. The Haemagglutinin (HA), Neuraminidase (NA) and Matrix (M2) proteins are embedded in the envelope lipid bilayer derived from the host cell (Kordyukova et al., 2019 (Figure No. 1). The M1 protein underlying the envelope is the major determinant of virion morphology [20]. The Nucleoprotein (NP) associates with each RNA segment to form the

Ribonucleoprotein (RNP) complex, which also contains small amounts of the three polymerase subunits. The non-structural proteins NS1 and NS2 are found only in infected cells ((Kordyukova et al., 2019).

The natural reservoir hosts of avian influenza viruses are wild water birds but infection of this viruses typically causes no or very little disease because influenza a virus stick together in nearly good balance with the hosts (Clark et al., 2006). The viruses are equal and crucial pathogens for animals as well as human. In humans, influenza causes a profuse contagious respiratory disease that in majority of cases is self-limiting but yet causes enough morbidity and mortality globally (Vahlenkamp et al., 2021). Presently, no practical, specific treatment exists for AI virus infections in commercial poultry and antiviral resistance is an increasingly important issue because human avian influenza vaccines are not yet widely available, and treatment of human infections is currently limited to supportive therapy and treatment with antivirals (Beigel et al., 2008). The avian influenza virus is hard to control because of the frequent contact with chickens, ducks in the live poultry markets and the birds in our daily life. In addition, the migration of the wild birds from one area to another every year in the world made the viruses transmit more in the world (Reed et al., 2003). Important factors often overlooked in avian influenza risk analyses are that vaccination, and concurrent infection by low-pathogenic avian influenza viruses, do not prevent poultry from becoming infected with the H5N1 highly pathogenic influenza virus but can prevent poultry infected from exhibiting disease symptoms or mortality (Abdelwhab et al., 2012).

On the basis of pathogenicity the bird flu disease is categorized into two types like as High Pathogenic Avian Influenza and low Pathogenic Avian Influenza.

1.1 Low Pathogenic Avian Influenza:- is a mild form of avian influenza caused mainly by influenza A viruses of the H5 and H7 subtypes. Unlike highly pathogenic strains, LPAI usually produces little or no visible illness in birds, often causing only mild respiratory signs, reduced egg production, or no symptoms at all. Because infected birds may appear healthy, the virus can spread silently through poultry flocks and wild birds, making early detection and monitoring essential. Although LPAI generally poses minimal risk to humans, certain strains have the potential to mutate into highly pathogenic forms, which can lead to severe outbreaks. Therefore, surveillance, biosecurity, and timely vaccination are key components in preventing the evolution and spread of LPAI in poultry populations.

1.2 Highly Pathogenic Avian Influenza Virus:- This type of influenza virus is an extremely contagious, multi-organ systemic disease and is a listed disease of World Organization for Animal Health and there is risk of spread of the disease beyond the national boundaries. Control is difficult due to extreme genetic alteration. Earlier the AIV H5N1 subtype was restricted to poultry but now involves migratory birds also and has emerged in mammals and among human population too (Alexander, 2007). In the 31 years from 1959 to 1990, there were nine HPAI virus outbreaks recorded in Europe, North America, and Australia, and these outbreaks were contained by the "stamping out" of infected flocks (Sims et al., 2008). In the 11 years since 1990, there have been 10 further HPAI virus outbreaks, including in Asia. The current HPAI H5N1 virus outbreak (from 2003 onwards) is, however, unprecedented in scale and geographic distribution. These viruses are now panzootic across three continents, leading to huge economic losses, and have transmitted to humans with lethal consequences. The expansion of intensive poultry husbandry, which is the fastest growing livestock industry globally, with an estimated 16 billion chickens and 1 billion ducks worldwide, is likely facilitating the increasing frequency and scale of HPAI virus outbreaks (Gilbert et al., 2017). Furthermore, the commercialized large-scale poultry industry is now associated with the movement of live poultry and poultry products over long distances, thereby facilitating the transmission of infection. On the basis of the genetic sequence of HA and the biological properties of the virus, it appears that the avian influenza viruses that contributed to the origin of the pandemics of 1957 and 1968 were LPAI viruses of chicken and other terrestrial poultry (Nagarajan et al., 2020). Therefore, for pandemic preparedness, surveillance of poultry and other avian species must be directed at healthy as well as diseased birds. On the other hand, reconstruction of the H1N1 virus causing the "Spanish flu" pandemic of 1918 suggests that this virus may have had high pathogenicity for terrestrial poultry even though it did not have the multibasic cleavage site in the HA that characterizes HPAI virus (Fontana et al., 2014). However, direct proof of high pathogenicity of the 1918 virus for chickens is still awaited.

1.3 Symptoms of Avian Influenza:- Avian influenza infections may produce a mild disease manifested by a variety of respiratory, enteric or reproductive signs (depending on the strain).

1. Clinical signs may include decreases in activity, food consumption or egg production, coughing and sneezing, ruffled feathers, diarrhea and/or tremors (Alexander, 2008). At times,

few visible clinical signs are noted and without specific laboratory testing, some LPAI outbreaks may go entirely undetected.

2. Human infections can be acquired through direct contact with infected animals or contaminated environments. Infection of humans by A (H5) or A (H7N9) avian influenza viruses has an aggressive clinical course.

3. Initial symptoms are high fever (≥ 38°C) and cough. Dyspnoea or difficulty in breathing is also sign and symptom of lower respiratory tract. Sore throat or coryza is a less common symptom of the upper respiratory tract.

4. Other symptoms such as diarrhea, vomiting, abdominal pain, bleeding from the nose or gums, and chest pain have also been reported in some patients. Complications of infection include hypoxemia, multiple organ dysfunction, and secondary bacterial and fungal infections (Yu et al., 2013 & Kapoor et al., 2014)

1.4 Clinical diagnosis: Avian influenza viruses can be detected in oropharyngeal, tracheal and/or cloacal swabs from live birds, with differing recovery rates from each site depending on the virus, species of bird and other factors (Killian, 2014) . Very small swabs can be valuable in small birds, but feces can be substituted if cloacal samples are not practical (e.g., can not be collected without harming the bird) (Abdelwhab, 2012) . Immature feathers may also be a useful sample (Azeem et al., 2023). Samples from internal organs are also tested in dead birds suspected of having HPAI.

Figure No. 2: A swab test performed to identify avian influenza (source: adapted from The Mercury News) (**Source:** https://www.mercurynews.com/2024/04/01/second-reported-case-of-bird-flu-in-a-person-in-the-us-confirmed/)

A fixed diagnosis of bird flu is proved by direct detection of bird flu viral proteins or genes in specimens like as tissues, cell cultures, embryonating eggs or by isolation and identification of bird flu virus (George , 2012) or by a molecular detection. Clinically the disease is indistinguishable because lesions and symptoms are to variable and confuse with other diseases and Avian Influenza virus cannot be diagnosed by clinical signs and symptoms alone. Therefore, confirmation should be undertaken by specialized laboratories, serology and virology are necessary. There is different virus isolation techniques described below.

1.4.1 Virus isolation: virus isolation by inoculating the sample into hatching chicken eggs for detecting a property of red blood cells precipitation can be performed in all species, and can be useful for virus characterization (Leland, 2016) . This technique is the "gold standard" but laborious and time insensitive, used primarily for diagnosis of first clinical case and to obtain virus isolated for further laboratory analysis.

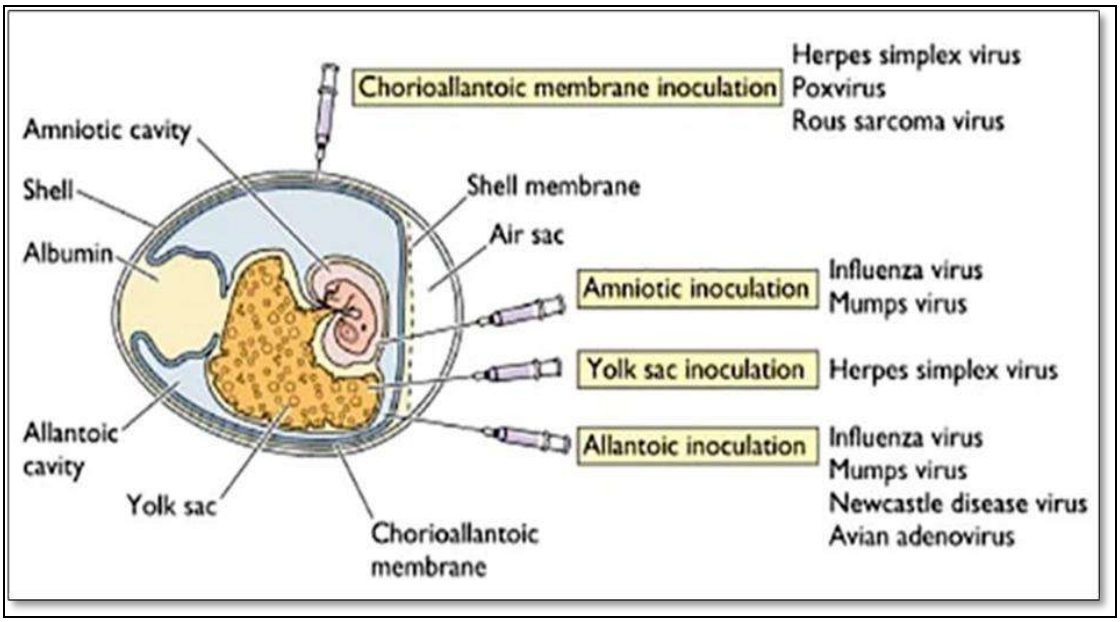

Figure No. 3: Culturing of influenza virus by using chicken embryonated egg (**Source**: adapted from Microbiology Info.com, https://microbiologyinfo.com/techniques-of-virus-cultivation/)

1.4.2 Serological test:- laboratory diagnosis of bird flu viruses can also be performed by serological test such as hemagglutinin inhibition test, Agar Gel Immune Diffusion (AGID), antigen-detection ELISAs or other immunoassays, and molecular test by using RT-PCR (Das, 2025).

a. Hemagglutination inhibition test:- The viruses can be identified as influenza A viruses with hemagglutination inhibition test, in which the Hemagglutinin (HA) protein of avian influenza has the property to agglutinate erythrocytes from a number of species including horses (Pedersen, 2008). A specific antibody to the antigenic sites on the avian influenza HA molecule prevents or inhibits the hemagglutination reaction. Therefore, hemagglutination inhibition test can be used to type the patient antibodies to avian influenza virus when standard avian influenza antigen is available as reference material (Meijer et al., 2006).

1.4.3 Antigen-detection ELISAs: An antigen- detection ELISA for bird flu is a rapid test that determines the presence of virus nucleoprotein from Type A influenza in poultry using a sandwich immunoassay. In this method monoclonal antibodies are used to capture the viral antigen from samples such as cloacal or tracheal swabs of poultry, after that virus is detected with an enzyme linked antibody. This test provides the fast and inexpensive screening tool for the presence or absence of the virus.

1.4.4 Agar gel immune diffusion test:- Use of the AGID test to demonstrate nucleocapsid or matrix antigens is also a satisfactory way to indicate the presence of influenza A virus in amnioallantoic and chorioallantoic fluid, but various experimental and commercial rapid, solid-phase antigen-capture ELISAs (AC-ELISAs) are an effective alternative [34]. They use a monoclonal antibody against the nucleoprotein; they should be able to detect any influenza A virus. The main advantage of these tests is that they can demonstrate the presence of influenza A within 15 minutes. The disadvantages are that they may lack sensitivity, they may not have been validated for different species of birds, subtype identification is not achieved and the kits are expensive (Gashaw, 20200).

1.4.5 Reverse Transcriptase Polymerase Chain Reaction:- (RT-PCR) is another powerful technique for the identification of influenza virus genomes and allow for sensitive and specific detection of viral nucleic acid (Merckx et al., 2017). RT-PCR techniques on clinical specimens can, with the correctly defined primers, result in rapid detection and subtype identification (at least of H5 and H7), including a DNA product that can be used for nucleotide sequencing (Sidoti et al., 2017). However, the preferred molecular detection tests for influenza A virus is the real-time RTPCR, a modification to the RT-PCR that reduces the time for both identification of virus subtype and sequencing (George et al., 2012). A disadvantage of RT PCR methods is its

proneness for contamination and the consequent risk of false positive results (Merckx et al., 2017).

1.4.6 Reporting on Prevention and Control of Disease:- A fast response is necessary for bird flu outbreaks, and in some cases, for minimizing the risk of zoonotic transmission. In addition to national notification requirements, HPAI viruses and LPAI viruses that contain H5 or H7 must be reported to the OIE by member nations (Hassan et al., 2010).

1. Veterinarians who encounter or suspect a reportable disease should follow their country-specific guidelines for informing the proper authorities (state or federal veterinary authorities in the India). Unusual mortality among wild birds should also be reported (e.g., to state, tribal or federal natural resource agencies in the U.S (Das , 2025).

2. The control of AI in poultry, from village to commercial sectors, requires farm-to-table risk management. Some of the basic needs include implementation of good agricultural practices such as training of workers in good management and biosecurity practices, supplying a source of potable water, providing a feed supply that is secure and free of contaminants, disinfection and decontamination of the premises and equipment prior to the introduction of a new flock or after culling of poultry flocks, establishing routine composting of litter and carcasses for all flocks, and safe disposal of carcasses from known infected farms (Brglez et al., 2008).

3. Avoiding contact with sick animals, animals known to be infected, and their environments; employing good sanitation and hygiene (e.g., hand washing); and using Personal Protective Equipment where appropriate (Elchos et al., 2008).

4.Vaccination of poultry against avian influenza with inactivated vaccines and live recombinant vaccines (fowl pox H5) has the capacity to increase resistance to infection, to protect poultry from clinical disease and to reduce shedding of virus if vaccinated poultry become infected (Suarez et al., 2017). So, well-managed vaccination of poultry can reduce the mortality and morbidity rate and the risk to humans by reducing the quantity of circulating virus (Raphael et al., 2025).

In addition to this, annual influenza vaccination is also the best public health intervention to prevent human influenza and available in two trivalent formulations inactivated and live-attenuated that contains an A (H1N1), an A (H3N2), and a B virus strain. In the field of influenza vaccination, neither commercially available nor experimentally tested vaccines have been shown so far to fulfil all of the requirements (Tsilibary et al., 2021)

2.CONCLUSION

As poultry production increases, poultry farms will be forced to become larger in size with greater numbers of birds. The demand for increased production will force producers to be efficient, and decreasing losses will be crucial, yet highly populated poultry farms will likely only increase the chance of incurring losses due to infectious disease. Simply put, traditional systems of monitoring disease and infection will not be sufficient if future production goals are to be achieved. Instead, rapid detection systems that constantly monitor poultry for disease can complement pre-existing systems of infectious disease detection and diagnosis. Rapid real-time detection can alert and locate producers to problems immediately. Additionally, biosensors will provide producers with a specific diagnosis that is performed on-site. The combination of early detection and rapid diagnosis provides great value to producers as it allows for immediate action to be taken in order to prevent any subsequent spread of infection to other birds, therefore saving potential losses that likely would have occurred had traditional methods been used. As these devices become common on farms, they will also provide data that could help predict emerging diseases in poultry. In addition to farm generated data, web-based, environmental, and geographical data will also become important for collection and inclusion in predictive models. The dynamic data that will be included in these models will require systems of big data analytics in order to account for the volume and variety of the data in addition to the need for real-time analysis. The implementation of technologies in the poultry production industry that enhance detection, diagnosis, and prediction of infectious diseases currently faces multiple challenges, however they will be necessary to achieve rates of production required in the future.

3. DECLARATIONS

3.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

3.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

3.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

4.REFERENCES:

1. Attia, Y.A., Rahman, M.T., Hossain, M.J., Basiouni, S., Khafaga, A.F., Shehata, A.A. & Hafez, H.M. (2022). Poultry production and sustainability in developing countries under the COVID-19 crisis: Lessons learned. *Animals*, *12*(5), p.644.
2. Nadathur, S.R., Wanasundara, J.P.D. & Scanlin, L. (2017). Proteins in the diet: Challenges in feeding the global population. In *Sustainable protein sources* (pp. 1-19). Academic Press.
3. Kleyn, F.J. & Ciacciariello, M. (2021). Future demands of the poultry industry: will we meet our commitments sustainably in developed and developing economies?. *World's Poultry Science Journal*, *77*(2), pp.267-278.
4. Nkukwana, T.T. (2018). Global poultry production: Current impact and future outlook on the South African poultry industry. *South African Journal of Animal Science*, *48*(5), pp.869-884.
5. Mor-Mur, M. & Yuste, J. (2010). Emerging bacterial pathogens in meat and poultry: an overview. *Food and Bioprocess Technology*, *3*(1), pp.24-35.
6. Bengis, R.G., Leighton, F.A., Fischer, J.R., Artois, M., Morner, T. & Tate, C.M. (2004). The role of wildlife in emerging and re-emerging zoonoses. *Revue scientifique et technique-office international des epizooties*, *23*(2), pp.497-512.
7. Greger, M. (2007). The human/animal interface: emergence and resurgence of zoonotic infectious diseases. *Critical reviews in microbiology*, *33*(4), pp.243-299.
8. Dangi, T. & Jain, A. (2012). Influenza virus: a brief overview. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences*, *82*(1), pp.111-121.
9. Gholizadeh, O., Akbarzadeh, S., Ghazanfari Hashemi, M., Gholami, M., Amini, P., Yekanipour, Z., Tabatabaie, R., Yasamineh, S., Hosseini, P. & Poortahmasebi, V. (2023). Hepatitis A: viral structure, classification, life cycle, clinical symptoms, diagnosis error, and vaccination. *Canadian Journal of Infectious Diseases and Medical Microbiology*, *2023*(1), p.4263309.
10. Perdue, M.L. & Suarez, D.L. (2000). Structural features of the avian influenza virus hemagglutinin that influence virulence. *Veterinary microbiology*, *74*(1-2), pp.77-86.
11. Russell, R.J., Gamblin, S.J. & Skehel, J.J. (2013). Influenza glycoproteins: Hemagglutinin and neuraminidase. *Textbook of influenza*, pp.67-100.

12. Ciminski, K. & Schwemmle, M. (2021). Bat-borne influenza A viruses: an awakening. *Cold Spring Harbor Perspectives in Medicine*, *11*(2), p.a038612

13. Kordyukova, L.V., Shtykova, E.V., Baratova, L.A., Svergun, D.I. & Batishchev, O.V. (2019). Matrix proteins of enveloped viruses: a case study of Influenza A virus M1 protein. *Journal of Biomolecular Structure and Dynamics*, *37*(3), pp.671-690.

14. Clark, L. & Hall, J. (2006). Avian influenza in wild birds: status as reservoirs, and risks to humans and agriculture. *Ornithological monographs*, pp.3-29.

15. Vahlenkamp, T.W. & Sykes, J.E. (2021). Influenza virus infections. In *Greene's Infectious Diseases of the Dog and Cat* (pp. 310-320). WB Saunders.

16. Beigel, J. & Bray, M. (2008). Current and future antiviral therapy of severe seasonal and avian influenza. *Antiviral research*, *78*(1), pp.91-102.

17. Reed, K.D., Meece, J.K., Henkel, J.S. & Shukla, S.K. (2003). Birds, migration and emerging zoonoses: West Nile virus, Lyme disease, influenza A and enteropathogens. *Clinical medicine & research*, *1*(1), pp.5-12.

18. Abdelwhab, E.M. & Hafez, H.M. (2012). Insight into alternative approaches for control of avian influenza in poultry, with emphasis on highly pathogenic H5N1. *Viruses*, *4*(11), pp.3179-3208.

19. Alexander, D.J. (2007). An overview of the epidemiology of avian influenza. *Vaccine*, *25*(30), pp.5637-5644.

20. Sims, L.D. & Brown, I.H. (2008). Multicontinental epidemic of H5N1 HPAI virus (1996–2007). *Avian influenza*, pp.251-286.

21. Gilbert, M., Xiao, X. & Robinson, T.P. (2017). Intensifying poultry production systems and the emergence of avian influenza in China: a 'One Health/Ecohealth'epitome. *Archives of public health*, *75*(1), p.48.

22. Nagarajan, S., Kumar, M., Murugkar, H.V., Tosh, C. & Singh, V.P. (2020). Avian Influenza Virus. In *Animal-Origin Viral Zoonoses* (pp. 111-133). Singapore: Springer Singapore.

23. Fontana, J.M., Eiras, D.P., Salvatore, M. & Singh, S.K. (2014). Human influenza virus infections. *Human respiratory viral infections*, *411*.

24. Alexander, D.J. (2008). Avian influenza–diagnosis. *Zoonoses and public health*, *55*(1), pp.16-23.

25. Yu, L., Wang, Z., Chen, Y., Ding, W., Jia, H., Chan, J.F.W., To, K.K.W., Chen, H., Yang, Y., Liang, W. & Zheng, S. (2013). Clinical, virological, and histopathological manifestations of fatal human infections by avian influenza A (H7N9) virus. *Clinical infectious diseases*, *57*(10), pp.1449-1457

26. Kapoor, S. & Dhama, K. (2014). Clinical features of influenza viruses. In *Insight into Influenza Viruses of Animals and Humans* (pp. 103-114). Cham: Springer International Publishing.

27. Killian, M.L. (2014). Avian influenza virus sample types, collection, and handling. In *Animal Influenza Virus* (pp. 83-91). New York, NY: Springer New York.

28. Azeem, S., Guo, B., Sato, Y., Gauger, P.C., Wolc, A. & Yoon, K.J. (2023). Utility of feathers for avian influenza virus detection in commercial poultry. *Pathogens*, *12*(12), p.1425.

29. George, K.S. (2012). Diagnosis of influenza virus. In *Influenza Virus: Methods and Protocols* (pp. 53-69). Totowa, NJ: Humana Press

30. Leland, D. & Landry, M.L. (2016). Virus isolation. In *Lennette's Laboratory Diagnosis of Viral Infections* (pp. 98-112). CRC Press.

31. Das, S., Goswami, S., Agarwal, S. & Das, D., Clinical Examination, Immunoassays, and Molecular Diagnostic Techniques for Emerging and Re-Emerging Diseases of Viral Origin. In *Emerging and Re-Emerging Viral Diseases* (pp. 170-188). CRC Press.

32. Pedersen, J.C. (2008). Hemagglutination-inhibition test for avian influenza virus subtype identification and the detection and quantitation of serum antibodies to the avian influenza virus. In *Avian influenza virus* (pp. 53-66). Totowa, NJ: Humana Press.

33. Meijer, A., Bosman, A., Van De Kamp, E.E., Wilbrink, B., van Beest Holle, M.D.R. & Koopmans, M. (2006). Measurement of antibodies to avian influenza virus A (H7N7) in humans by hemagglutination inhibition test. *Journal of virological methods*, *132*(1-2), pp.113-120.

34. Gashaw, M. (2020). A review on avian influenza and its economic and public health impact. *Int J Vet Sci Technol*, *4*(1), pp.15-27.

35. Merckx, J., Wali, R., Schiller, I., Caya, C., Gore, G.C., Chartrand, C., Dendukuri, N. & Papenburg, J. (2017). Diagnostic accuracy of novel and traditional rapid tests for

influenza infection compared with reverse transcriptase polymerase chain reaction: a systematic review and meta-analysis. *Annals of internal medicine*, *167*(6), pp.394-409.

36. Sidoti, F., Rizzo, F., Costa, C., Astegiano, S., Curtoni, A., Mandola, M.L., Cavallo, R. & Bergallo, M. (2010). Development of real time RT-PCR assays for detection of type A influenza virus and for subtyping of avian H5 and H7 hemagglutinin subtypes. *Molecular biotechnology*, *44*(1), pp.41-50.

37. Hassan, M.S. & Abdul-Careem, M.F. (2020). Avian viruses that impact table egg production. *Animals*, *10*(10), p.1747.

38. Brglez, B. & Hahn, J. (2008). Methods for disposal of poultry carcasses. *Avian influenza*, pp.333-352.

39. Elchos, B.L., Scheftel, J.M., Cherry, B., DeBess, E.E., Hopkins, S.G., Levine, J.F. & Williams, C.J. (2008). Compendium of veterinary standard precautions for zoonotic disease prevention in veterinary personnel. *Journal of the American Veterinary Medical Association*, *233*(3), pp.415-432.

40. Suarez, D.L. & Pantin-Jackwood, M.J. (2017). Recombinant viral-vectored vaccines for the control of avian influenza in poultry. *Veterinary microbiology*, *206*, pp.144-151.

41. Tsilibary, E.P., Charonis, S.A. & Georgopoulos, A.P. (2021). Vaccines for influenza. *Vaccines*, *9*(1), p.47.

42. Raphael, F.O., Okoh, O.F., Omachi, A. & Abiojo, A.D. (2025). Economic Implications of Avian Influenza Vaccination Programs in Poultry Production. *International Journal of Advance Research Publication and Reviews*, *2*(4), pp.10-34.

43. https://knowablemagazine.org/content/article/health-disease/2025/scientific-facts-about-h5n1-bird-flu

44. https://www.mercurynews.com/2024/04/01/second-reported-case-of-bird-flu-in-a-person-in-the-us-confirmed/

45. https://microbiologyinfo.com/techniques-of-virus-cultivation/

Artificial Intelligence in Antimicrobial Resistance (AMR) Prediction: Current Approaches and Future Perspectives – A narrative review

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ABSTRACT

Antimicrobial resistance (AMR) is eroding the effectiveness of existing therapies and straining clinical workflows that depend on slow, culture-based testing. Over the past five years, advances in artificial intelligence (AI) including classical machine learning, deep neural networks, and graph-based models have opened new avenues for predicting resistance phenotypes and accelerating diagnostics. This review synthesizes methods that learn from diverse data streams such as whole-genome sequences, metagenomes, mass spectrometry profiles, electronic health records, and hospital epidemiology logs to infer pathogen identity, resistance mechanisms, and likely antimicrobial susceptibility. We compare modeling choices (feature-engineered vs. representation-learning approaches), highlight best practices for dataset curation and external validation, and summarize clinical applications spanning rapid AST triage, resistance gene discovery, outbreak surveillance, and antibiotic stewardship decision support. Key limitations persist noisy and imbalanced datasets, population and domain shift, limited model interpretability, privacy concerns, and hurdles to prospective, multi-site evaluation. Looking ahead, we outline opportunities in multimodal foundation models, explainable and causally informed learning, federated and privacy-preserving training, adaptive calibration, and standardized reporting that links algorithmic outputs to actionable care pathways. Taken together, the evidence indicates that carefully validated AI systems can complement laboratory testing and surveillance networks, shortening time-to-therapy and enabling more targeted use of antimicrobials while mitigating unintended risks.

Keywords: Antimicrobial Resistance, Deep Learning, Artificial Intelligence, Machine Learning, MALDI-TOF Mass Spectrometry.

1. INTRODUCTION

Antimicrobial resistance (AMR) is a growing global health concern. In 2019 AMR was associated with roughly 4.95 million deaths worldwide, and it is projected to cause up to 10 million deaths per year by 2050 (Arnold A et al., 2025). The irrational use of antibiotics in medicine and agriculture has accelerated this trend, while the pipeline for new antibiotics has dwindled.[2] In this context, artificial intelligence (AI) and machine learning (ML) have emerged as powerful tools to tackle AMR. By extracting patterns from large, complex datasets (e.g. genomes, electronic health records, or spectra), AI/ML methods can predict resistance phenotypes faster than traditional lab tests (Lastra JMP, et al., 2024 and Sakagianni A et al., 2023). Recent reviews emphasize that AI/ML facilitates efficient analysis of big data, enabling reliable prediction of resistance trends and informing personalized treatment decisions(Lastra JMP, et al., 2024 and Sakagianni A et al., 2023). As Pérez de la Lastra et al. note, "AI/ML algorithms have emerged as powerful tools for combating AMR" by identifying resistance markers and predicting treatment outcomes from genomics and clinical data. In short, integrating AI into antimicrobial stewardship could improve diagnostic speed and accuracy, helping clinicians select effective therapies and curb the spread of resistant pathogens ((Lastra JMP, et al., 2024 and Cavallaro M et al., 2023).

Conventional antimicrobial susceptibility testing (AST) methods, while reliable, require 24–72 hours or longer generating results. This diagnostic delay often necessitates empiric broad-spectrum antibiotic therapy, which increases selective pressure and further accelerates resistance. AI and ML methods are increasingly being applied to circumvent these limitations. By leveraging large datasets including electronic health records (EHRs), local antibiograms, genomic data, and mass spectrometry profiles AI can provide rapid, data-driven insights into pathogen identification and resistance phenotypes. Several comprehensive reviews highlight how ML pipelines have been successfully integrated into microbiology workflows, yielding faster and more accurate predictions than traditional approaches (Marongiu L et al., 2022; Zhang RG et al.,2023; Kalantar KL et al., 2021) .

Genomics-driven AMR prediction has become a particularly powerful domain. Whole genome sequencing (WGS) allows resistance profiles to be inferred either through knowledge-driven

approaches where isolates are scanned against curated antimicrobial resistance gene (ARG) databases such as CARD, ResFinder, MEGARes, and ARG-ANNOTor through data-driven ML approaches that identify complex patterns, such as k-mer signatures or single-nucleotide polymorphisms, predictive of resistance phenotypes.[8] The former strategies offer interpretability and robustness, while the latter can detect novel mechanisms of resistance. However, pattern-driven models are sensitive to data imbalance, noise, and site-specific distribution shifts, often resulting in poor generalization across geographic regions. Thus, recent studies emphasize the importance of harmonized training datasets, cross-validation across multiple sites, and the development of standardized reporting frameworks to enhance reproducibility and clinical applicability (Bortolaia V et al., 2020; Doster E et al., 2020 and Zhang RG et al.,2023).

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) is a mainstay in clinical microbiology laboratories due to its rapid and cost-effective capability for species-level identification. Recent advances have extended its utility toward antimicrobial resistance (AMR) prediction by coupling MALDI-TOF data with supervised machine-learning algorithms. For instance, using a dataset of over 20,000 clinical *S. aureus* isolates, researchers constructed an ML model that distinguished methicillin-resistant *S. aureus* (MRSA) from methicillin-susceptible strains with an AUC ranging between 0.78 and 0.88 across multiple external test sites; model interpretability was enhanced using SHAP explanations, and specific m/z features were identified as biomarkers.[11] Similarly, a random forest model trained on full-spectrum MALDI-TOF profiles of *K. pneumoniae* achieved 97% overall accuracy in distinguishing carbapenem-resistant from carbapenem-sensitive isolates, with 93% sensitivity and 100% specificity highlighting the technique's potential to reduce detection time to mere minutes (Taiwo B et al., 2013 and Gato E et al., 2023).

2. Current AI Approaches in AMR Prediction

Modern AMR prediction relies on a variety of AI techniques. **Supervised ML models** are most common: linear/logistic regression, decision trees, support vector machines (SVM), k-nearest neighbors, random forests (RF), and gradient-boosting are widely used.[3] These models are typically trained on labeled data (e.g. genomes with known resistance profiles) to classify isolates as resistant or susceptible. For example, Ren et al. used logistic regression, SVM, RF and deep convolutional neural networks on whole-genome sequences to predict resistance to

antibiotics like ciprofloxacin and gentamicin; the RF and CNN models achieved AUCs up to 0.96.[13] In practice, researchers have applied decision-tree and ensemble methods to clinical cohorts: Goodman *et al.* built a decision tree to predict extended-spectrum β-lactamase (ESBL) production in *E. coli* and *Klebsiella* from patient data, and later studies used XGBoost to forecast resistance in Gram-negative bloodstream infections with higher accuracy than clinicians. Other studies have used Random Forests or neural networks on patient demographics and lab data, achieving AUROCs in the range of 0.72–0.93 for various settings (Sakagianni A et al., 2023).

Deep learning expands these capabilities by automatically learning complex features. For instance, López-Cortés *et al.* developed **MS Deep AMR**, a deep neural network that takes raw MALDI-TOF mass spectra as input to predict resistance in *E. coli*, *K. pneumoniae*, and *S. aureus*. MSDeepAMR yielded AUROC values above 0.83 in most cases, outperforming previous MALDI-based methods by over 10% (López-Cortés XA et al., 2024). Similarly, Ren et al. showed that a convolutional neural network (CNN) can encode whole-genome data (using techniques like one-hot encoding or frequency chaos game representation) to predict AMR: their CNN outperformed traditional models, also achieving AUC≈0.96 (López-Cortés XA et al., 2024). These examples illustrate that **deep neural networks**, including CNNs and multilayer perceptrons, can learn intricate genotype–phenotype relationships (even epistatic effects) from genomic or spectral data. However, they require large training datasets and careful tuning. In general, studies find that RF and CNN models often outperform simpler algorithms when ample data are available(Ren Y et al., 2022 and bdollahi-Arpanahi R et al., 2020).

Beyond these, hybrid approaches and specialized encodings are used. Genomic data can be transformed into input features via presence/absence of known resistance genes (gene-based encoding), specific mutations (mutation-based encoding), or k-mer counts (composition-based encoding) .[1,13] Researchers often combine genomic features with clinical or microbiological metadata to enrich predictions. For example, Pataki *et al.* used a gene- and mutation-based encoding of diverse *E. coli* genomes to train an RF that predicted ciprofloxacin minimum inhibitory concentrations by focusing on a few high-importance SNPs.[1] Machine learning pipelines may also involve feature-selection methods (e.g. mutual information tests or coefficient thresholds) to reduce dimensionality (Arnold A, et al., 2025 and Cavallaro M et al., 2023).

Overall, current approaches blend classic ML, deep learning, and feature-engineering to predict AMR phenotypes, with model choice often depending on data type and scale.

3. Applications in Clinical Microbiology

In modern clinical microbiology, AI-enhanced tools are increasingly reshaping workflows toward **rapid and accurate antimicrobial resistance (AMR) prediction**, thus enabling more effective antimicrobial stewardship and patient care.

3.1 MALDI-TOF MS Integrated with Machine Learning

Matrix-assisted laser desorption/ionization time-of-flight (MALDI-TOF) mass spectrometry, already prevalent for rapid microbial species identification, has now been leveraged with AI to predict resistance directly from spectral data.

- In a retrospective study analyzing nearly 12,000 *Klebsiella pneumoniae* isolates, researchers developed an AI-enhanced clinical decision support system (AI-CDSS) that paired MALDI-TOF spectra with machine learning algorithms. A random forest classifier achieved an impressive **AUC of 0.95** in predicting resistance to levofloxacin and ciprofloxacin (Jian MJ et al., 2024)
- Another investigation employed MALDI-TOF data and machine learning (including SVM, logistic regression, random forest, and CatBoost) to predict AMR in *Staphylococcus aureus*, *Escherichia coli*, and *K. pneumoniae*. Notably, CatBoost achieved **AUROC of 0.91** and an **F1 score of 0.78** for *E. coli*, while interpretability was enhanced via SHAP analysis of spectral biomarkers (López-Cortés XA et al., 2025).
- In *Staphylococcus epidermidis*, a study successfully used MALDI-TOF spectral data and machine learning to predict antibiotic resistance, with **AUROC scores ranging between 0.80–0.95** and **AUPRC up to 0.97**. SHAP analysis confirmed that predictive power stemmed from meaningful protein biomarkers rather than noise (Ren M et al., 2024).

These examples illustrate how **MALDI-TOF + ML** pipelines can compress time-to-result from days to minutes without additional assays thus enabling faster, AI-assisted clinical decisions.

3.2. Electronic Health Records (EHR) – ML for Resistance Prediction

Beyond laboratory data, EHRs are a rich but underutilized resource for early resistance prediction.

- A landmark study used readily available clinical parameters (demographics, hospital stay data, diagnoses, microbiological features) to develop ML models that predicted AMR in ICU pathogens. These models achieved **AUROC values between 0.88 and 0.89**, outperforming a baseline antibiogram-based approach (Wang T et al., 2021).
- More recently, a multimodal deep learning framework combined static patient features with multivariate time-series data (e.g., antibiotic administration and ventilator status) to predict emerging multidrug resistance in ICU settings. Importantly, it emphasized **interpretability**, allowing clinicians to understand why an alert was triggered (Martínez-Agüero S et al., 2024)
- Other studies demonstrated that affordable, real-time AMR prediction from ICU EHR data can be operationalized using deep learning, enabling seamless integration with existing clinical systems and providing immediate decision support (Hardan S et al., 2024)

These applications highlight how clinical metadata, especially when modeled with AI that respects interpretability and ease of integration, can support early, data-driven antimicrobial decisions sometimes before traditional diagnostics conclude.

3.3. Clinical Decision Support Systems (CDSS)

AI-based CDSS combine data inputs from laboratory and clinical sources to recommend empiric therapy tailored to patient risk.

- In the *Klebsiella pneumoniae* example above, the AI-CDSS merged MALDI-TOF with ML to support agent selection for quinolone antibiotics, demonstrating the feasibility of AI-augmented diagnostic platforms (Jian MJ et al., 2024).
- Reviews emphasize that AI-driven CDSS must be **accurate**, **interpretable**, and **clinician-friendly**. Tools that provide recommendations without explanation face

resistance from end-users; conversely, systems designed around transparent decision logic see higher adoption (Arnold A et al., 2025).

Such systems, when validated prospectively, have the potential to **reduce empiric broad-spectrum prescribing**, thereby aiding stewardship and improving outcomes.

Table 1: Clinical Microbiology Applications of AI in AMR Prediction

Application Area	Summary of AI Use & Performance	Highlights / Interpretation
MALDI-TOF MS + ML (Carbapenem-Resistant *K. pneumoniae*) (Wang J, et al., 2022)	RF, SVM, and SVM-K models achieved accuracy of 0.88-0.91, sensitivity 0.82-0.89, specificity 0.92-0.94; AUC up to 0.9356.	Rapid and cost-effective AMR detection via ML-enhanced spectra classification.
MALDI-TOF MS + ML (Carbapenemase-Producing *K. pneumoniae*) (Gato E et al., 2013)	Random forest model on full spectral profiles achieved 97.83% accuracy; SHAP confirmed full-proteome pattern as determinant.	ML increases diagnostic speed to minutes while retaining high accuracy.
Rapid AST from Blood Cultures (*E. coli* & *K. pneumoniae*) (Xu X et al., 2023)	Tree-based ML models leveraged binned MALDI spectra; key features (m/z 7870–7879, 4920–4929) identified via Shapley values.	Enables near real-time AMR alerts directly from positive blood culture data.
EHR-based ML for ICU MDRO Prediction (Li Y et al., 2024)	Models trained on EHR features (top 25) achieved AUROC ~0.786 (PLAGH-ICU) and ~0.744 (MIMIC-IV). SHAP values elucidated key feature contributions.	Offers early-warning system for MDRO risk at ICU admission with interpretable outputs.

3.4. Challenges & Limitations

Although artificial intelligence (AI) has shown remarkable promise for antimicrobial resistance (AMR) prediction, several critical challenges restrict its translation into routine clinical microbiology and global surveillance.

1. Data availability and quality The effectiveness of AI models depends heavily on rich, high-quality data. Unfortunately, AMR datasets remain fragmented clinical metadata are often poorly standardized or incomplete, impairing model reproducibility. The Lancet's AMR genomics surveillance series highlights the urgent need for global standardization in genomic data and metadata (Baker KS et al., 2023). Meanwhile, the World Health Organization's GLASS program covers 126 countries but also underscores significant reporting gaps from low-income and middle-income regions (LID,2023).

2. Imbalanced Resistance Phenotypes Resistance events like carbapenem-resistant *Klebsiella pneumoniae* are relatively rare in many datasets, leading to imbalanced classes that bias ML models toward high specificity but poor sensitivity. This makes identifying critical resistance cases challenging an obstacle consistently reported in recent evaluations (Baker KS et al., 2023)

3. Interpretability ("Black-Box" Problem) Deep learning techniques (e.g., convolutional neural networks) capture complex relationships effectively but often lack transparency. Such "black-box" behavior hinders clinical trust, as practitioners cannot readily discern which genomic markers or spectral data drove a prediction. Explainable AI tools like SHAP and LIME offer potential, but their adoption in AMR tools remains limited (Nazir S et al., 2023)

4. Clinical Workflow Integration For AI models to be practical, they must integrate seamlessly with existing laboratory and electronic health record (EHR) systems. Interoperability challenges and lack of prospective validation frequently prevent clinical deployment. The Lancet Digital Health commentary notes that while AI shows promise, its clinical impact has been limited by these workflow barriers (Rawson TM et al., 2024).

5. Ethical and Regulatory Challenges Incorporating AI into antibiotic prescription raises complex ethical considerations balancing individual patient outcomes with societal impacts on

resistance. Regulatory frameworks are still catching up: accountability structures, approval pathways, and governance guidelines remain underdeveloped (Lekadir K et al., 2023)

Table 2: Challenges and Suggested Mitigations in AI-driven AMR Prediction

Challenge	Description	Suggested Response
Data Quality & Standardization (Cesaro A et al., 2023)	Fragmented datasets, incomplete metadata, limited interoperability	Develop unified standards; harmonize One Health surveillance
Phenotype Imbalance (Ali T et al., 2023)	Low prevalence resistant isolates → poor sensitivity of models	Oversampling, domain adaptation, cost-sensitive ML approaches
Interpretability ("Black-Box") (Perrella A et al., 2024)	Deep learning models lack transparency; clinicians hesitant to trust	Use SHAP/LIME; adopt inherently interpretable ML for critical applications
Workflow Integration (Howard A et al., 2024)	AI tools often fail to integrate into EHR and lab systems	Pilot projects with clinicians; ensure semantic/technical interoperability
Ethical/Regulatory Frameworks (Pennisi F et al., 2025)	Lack of governance, fairness, and accountability in AI recommendations	Establish clear regulatory pathways; ensure stakeholder and patient-centric governance

4. Future Directions

Artificial intelligence (AI) in antimicrobial resistance (AMR) prediction is advancing rapidly, yet its long-term success depends on addressing current limitations and strategically developing the next generation of tools. Several promising avenues are emerging.

4.1. Explainable and Trustworthy AI

One of the most important priorities is the development of **explainable AI (XAI)** models that balance predictive performance with transparency. Clinical adoption will require tools that not

only predict resistance but also clarify *why* a decision was made. Recent work in infectious disease diagnostics has shown how explainability frameworks such as SHAP (Shapley additive explanations) and counterfactual reasoning can provide human-readable outputs that highlight key features driving predictions. Cesaro *et al.* emphasize that embedding explainability into AMR prediction pipelines could significantly improve clinician confidence and regulatory acceptance (Mohapatra RK et al., 2025 and Cesaro A et al., 2025)

4.2. Point-of-Care AI Diagnostics

Rapid **point-of-care (POC)** tools integrated with AI are another promising frontier. Miniaturized sequencing devices and portable biosensors are being developed to deliver near-real-time data from patient samples. Coupling these with ML classifiers could enable clinicians to predict resistance directly at the bedside, bypassing lengthy laboratory workflows. For example, portable nanopore sequencing has been tested in field settings, with AI models accelerating resistance gene detection within hours (LID, 2023). This vision aligns with the WHO's call for decentralized diagnostics to support both high-income and resource-limited settings.

4.3. Global Surveillance Networks

AI also has an essential role in global AMR surveillance under the **One Health** framework. Models trained on geographically diverse datasets can identify emerging resistance hotspots and predict their international spread. Howard *et al.* note that harmonized global datasets, integrated with AI, will be critical to inform policy, prioritize new drug development, and allocate stewardship resources (Howard A et al., 2024). Efforts are underway to link national repositories into federated learning systems, allowing AI models to be trained collaboratively without requiring sensitive data to cross borders (Fu Q et al., 2025).

4.4. Integration with Antimicrobial Stewardship Programs

Future AI tools will need to move beyond prediction into **decision-support integration** with antimicrobial stewardship programs (ASPs). Pennisi *et al.* argue that next-generation AI systems should provide not only susceptibility predictions but also context-sensitive prescribing recommendations that align with stewardship principles such as reducing unnecessary use of

broad-spectrum agents (Pennisi F et al., 2025 and Pinto-de-Sá R , 2024). Embedding AI into stewardship workflows will be key to translating predictive accuracy into measurable public health benefit.

5.Conclusion

Antimicrobial resistance (AMR) is a global health crisis that continues to erode the effectiveness of frontline and last-resort antibiotics. Traditional culture-based diagnostic methods are too slow to guide timely therapy, contributing to inappropriate prescribing and worsening resistance trends. Artificial intelligence (AI) offers a pathway to accelerate detection, enhance surveillance, and support stewardship programs by extracting actionable insights from complex genomic, phenotypic, and clinical datasets. Recent applications of machine learning to MALDI-TOF spectra and whole-genome sequencing have already demonstrated significant reductions in time-to-result and improvements in prediction accuracy (Le Menestrel A et al, 2021). Nevertheless, challenges remain. Data fragmentation, class imbalance, and the "black-box" nature of many deep learning models hinder reproducibility and trust (Cesaro A et al., 2025). Moreover, integration into electronic health records and laboratory workflows requires technical and institutional readiness, while ethical concerns highlight the need to balance patient-centered care with population-level stewardship (Pennisi F et al., 2025). Without resolving these issues, AI will remain largely confined to research rather than routine practice. Looking ahead, the future of AI in AMR prediction depends on three priorities. First, explainable and trustworthy AI must become the norm to ensure clinician confidence. Second, point-of-care diagnostics, including portable sequencing and biosensor platforms, should be paired with AI for equitable, real-time predictions (LID, 2023). Finally, global One Health surveillance platforms, built on federated learning, are essential to detect emerging resistance hotspots without compromising data sovereignty. Achieving these milestones will transform AI from a promising research tool into a cornerstone of global AMR mitigation.

6. DECLARATIONS

6.1 CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest.

6.2 ETHICAL APPROVAL

No animals or human participants were included in the present study.

6.3 CONSENT FOR PUBLICATION

All the authors agree to submit for publication.

7.REFERENCES

1. Arnold A, McLellan S, Stokes JM. How AI can help us beat AMR. Npj Antimicrob Resist. 2025 Mar 13;3(1):18.
2. De La Lastra JMP, Wardell SJT, Pal T, De La Fuente-Nunez C, Pletzer D. From Data to Decisions: Leveraging Artificial Intelligence and Machine Learning in Combating Antimicrobial Resistance – a Comprehensive Review. J Med Syst. 2024 Aug 1;48(1):71.
3. Sakagianni A, Koufopoulou C, Feretzakis G, Kalles D, Verykios VS, Myrianthefs P, et al. Using Machine Learning to Predict Antimicrobial Resistance—A Literature Review. Antibiotics. 2023 Feb 24;12(3):452.
4. Cavallaro M, Moran E, Collyer B, McCarthy ND, Green C, Keeling MJ. Informing antimicrobial stewardship with explainable AI. Yoon D, editor. PLOS Digit Health. 2023 Jan 5;2(1):e0000162.
5. Marongiu L, Burkard M, Lauer UM, Hoelzle LE, Venturelli S. Reassessment of Historical Clinical Trials Supports the Effectiveness of Phage Therapy. Clin Microbiol Rev. 2022 Dec 21;35(4):e00062-22.
6. Zhang RG, Shang HY, Jia KH, Ma YP. Subgenome phasing for complex allopolyploidy: case-based benchmarking and recommendations. Brief Bioinform. 2023 Nov 22;25(1):bbad513.
7. Kalantar KL, Langelier CR. Host-Microbe Metagenomics: a Lens To Refocus Our Perspective on Infectious and Inflammatory Diseases. mSystems. 2021 Aug 31;6(4):10.1128/msystems.00404-21.
8. Taiwo B, Matining RM, Zheng L, Lederman MM, Rinaldo CR, Kim PS, et al. Associations of T cell activation and inflammatory biomarkers with virological response to darunavir/ritonavir plus raltegravir therapy. J Antimicrob Chemother. 2013 Aug 1;68(8):1857–61.

9. Bortolaia V, Kaas RS, Ruppe E, Roberts MC, Schwarz S, Cattoir V, et al. ResFinder 4.0 for predictions of phenotypes from genotypes. J Antimicrob Chemother. 2020 Dec 1;75(12):3491–500.

10. Doster E, Lakin SM, Dean CJ, Wolfe C, Young JG, Boucher C, et al. MEGARes 2.0: a database for classification of antimicrobial drug, biocide and metal resistance determinants in metagenomic sequence data. Nucleic Acids Res. 2020 Jan 8;48(D1):D561–9.

11. Le Menestrel A, Guerin F, Chau F, Massias L, Benchetrit L, Cattoir V, et al. Activity of the combination of colistin and fosfomycin against NDM-1-producing *Escherichia coli* with variable levels of susceptibility to colistin and fosfomycin in a murine model of peritonitis. J Antimicrob Chemother. 2021 Dec 24;77(1):155–63.

12. Gato E, Arroyo MJ, Méndez G, Candela A, Rodiño-Janeiro BK, Fernández J, et al. Direct Detection of Carbapenemase-Producing Klebsiella pneumoniae by MALDI-TOF Analysis of Full Spectra Applying Machine Learning. McElvania E, editor. J Clin Microbiol. 2023 June 20;61(6):e01751-22.

13. Ren Y, Chakraborty T, Doijad S, Falgenhauer L, Falgenhauer J, Goesmann A, et al. Prediction of antimicrobial resistance based on whole-genome sequencing and machine learning. Birol I, editor. Bioinformatics. 2022 Jan 3;38(2):325–34.

14. López-Cortés XA, Manríquez-Troncoso JM, Hernández-García R, Peralta D. MSDeepAMR: antimicrobial resistance prediction based on deep neural networks and transfer learning. Front Microbiol. 2024 Apr 17;15:1361795.

15. Abdollahi-Arpanahi R, Gianola D, Peñagaricano F. Deep learning versus parametric and ensemble methods for genomic prediction of complex phenotypes. Genet Sel Evol. 2020 Dec;52(1):12.

16. Jian MJ, Lin TH, Chung HY, Chang CK, Perng CL, Chang FY, et al. Pioneering Klebsiella Pneumoniae Antibiotic Resistance Prediction With Artificial Intelligence-Clinical Decision Support System–Enhanced Matrix-Assisted Laser Desorption/Ionization Time-of-Flight Mass Spectrometry: Retrospective Study. J Med Internet Res. 2024 Nov 7;26:e58039.

17. López-Cortés XA, Manríquez-Troncoso JM, Sepúlveda AY, Soto PS. Integrating Machine Learning with MALDI-TOF Mass Spectrometry for Rapid and Accurate

Antimicrobial Resistance Detection in Clinical Pathogens. Int J Mol Sci. 2025 Jan 28;26(3):1140.

18. Ren M, Chen Q, Zhang J. Repurposing MALDI-TOF MS for effective antibiotic resistance screening in Staphylococcus epidermidis using machine learning. Sci Rep. 2024 Oct 15;14(1):24139.

19. Wang T, Hansen KR, Loving J, Paschalidis ICh, van Aggelen H, Simhon E. Predicting Antimicrobial Resistance in the Intensive Care Unit [Internet]. arXiv; 2021 [cited 2025 Sept 2]. Available from: https://arxiv.org/abs/2111.03575

20. Martínez-Agüero S, Marques AG, Mora-Jiménez I, Alvárez-Rodríguez J, Soguero-Ruiz C. Multimodal Interpretable Data-Driven Models for Early Prediction of Antimicrobial Multidrug Resistance Using Multivariate Time-Series [Internet]. arXiv; 2024 [cited 2025 Sept 2]. Available from: https://arxiv.org/abs/2402.06295

21. Hardan S, Shaaban MA, Abdalla J, Yaqub M. Affordable and real-time antimicrobial resistance prediction from multimodal electronic health records. Sci Rep. 2024 July 16;14(1):16464.

22. Wang J, Xia C, Wu Y, Tian X, Zhang K, Wang Z. Rapid Detection of Carbapenem-Resistant Klebsiella pneumoniae Using Machine Learning and MALDI-TOF MS Platform. Infect Drug Resist. 2022 July;Volume 15:3703–10.

23. Xu X, Wang Z, Lu E, Lin T, Du H, Li Z, et al. Rapid detection of carbapenem-resistant Escherichia coli and carbapenem-resistant Klebsiella pneumoniae in positive blood cultures via MALDI-TOF MS and tree-based machine learning models. BMC Microbiol. 2025 Jan 24;25(1):44.

24. Li Y, Cao Y, Wang M, Wang L, Wu Y, Fang Y, et al. Development and validation of machine learning models to predict MDRO colonization or infection on ICU admission by using electronic health record data. Antimicrob Resist Infect Control. 2024 July 6;13(1):74.

25. Baker KS, Jauneikaite E, Nunn JG, Midega JT, Atun R, Holt KE, et al. Evidence review and recommendations for the implementation of genomics for antimicrobial resistance surveillance: reports from an international expert group. Lancet Microbe. 2023 Dec;4(12):e1035–9.

26. The Lancet Infectious Diseases. Antimicrobial resistance through the looking-GLASS. Lancet Infect Dis. 2023 Feb;23(2):131.

27. Nazir S, Dickson DM, Akram MU. Survey of explainable artificial intelligence techniques for biomedical imaging with deep neural networks. Comput Biol Med. 2023 Apr;156:106668.

28. Rawson TM, Zhu N, Galiwango R, Cocker D, Islam MS, Myall A, et al. Using digital health technologies to optimise antimicrobial use globally. Lancet Digit Health. 2024 Dec;6(12):e914–25.

29. Lekadir K, Feragen A, Fofanah AJ, Frangi AF, Buyx A, Emelie A, et al. FUTURE-AI: International consensus guideline for trustworthy and deployable artificial intelligence in healthcare [Internet]. arXiv; 2023 [cited 2025 Sept 2]. Available from: https://arxiv.org/abs/2309.12325

30. Cesaro A, Hoffman SC, Das P, De La Fuente-Nunez C. Challenges and applications of artificial intelligence in infectious diseases and antimicrobial resistance. Npj Antimicrob Resist. 2025 Jan 7;3(1):2.

31. Ali T, Ahmed S, Aslam M. Artificial Intelligence for Antimicrobial Resistance Prediction: Challenges and Opportunities towards Practical Implementation. Antibiotics. 2023 Mar 6;12(3):523.

32. Perrella A, Bernardi FF, Bisogno M, Trama U. Bridging the gap in AI integration: enhancing clinician education and establishing pharmaceutical-level regulation for ethical healthcare. Front Med. 2024 Dec 19;11:1514741.

33. Howard A, Aston S, Gerada A, Reza N, Bincalar J, Mwandumba H, et al. Antimicrobial learning systems: an implementation blueprint for artificial intelligence to tackle antimicrobial resistance. Lancet Digit Health. 2024 Jan;6(1):e79–86.

34. Pennisi F, Pinto A, Ricciardi GE, Signorelli C, Gianfredi V. The Role of Artificial Intelligence and Machine Learning Models in Antimicrobial Stewardship in Public Health: A Narrative Review. Antibiotics. 2025 Jan 30;14(2):134.

35. Mohapatra RK, Jolly L, Dakua SP. Advancing explainable AI in healthcare: Necessity, progress, and future directions. Comput Biol Chem. 2025 Dec;119:108599.

36. The Lancet Infectious Diseases. Antimicrobial resistance through the looking-GLASS. Lancet Infect Dis. 2023 Feb;23(2):131.

37. Fu Q, Zhang Y, Shu Y, Ding M, Yao L, Wang C. From Data to Action: Charting A Data-Driven Path to Combat Antimicrobial Resistance [Internet]. arXiv; 2025 [cited 2025 Sept 2]. Available from: https://arxiv.org/abs/2502.00061

38. Pinto-de-Sá R, Sousa-Pinto B, Costa-de-Oliveira S. Brave New World of Artificial Intelligence: Its Use in Antimicrobial Stewardship—A Systematic Review. Antibiotics. 2024 Mar 28;13(4):307.

ABOUT THE UNIVERSITY

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