



**INTERNATIONAL JOURNAL OF
PHARMACEUTICAL SCIENCES**
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: <https://www.ijpsjournal.com>



Review Article

Design and Optimization of 'Green Guard' Biodegradable Face Masks Incorporating Herbal Extracts for Antimicrobial Properties

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ARTICLE INFO

Published: 06 June 2025

Keywords:

Herbal-coated masks,
antimicrobial properties,
Airborne disease prevention,
Mint, Acacia catechu,
Nutmeg, Sustainable PPE,
COVID 19

DOI:

10.5281/zenodo.15605625

ABSTRACT

Public health is seriously threatened by airborne infections, which are brought on by bacteria, viruses, and fungi. Although surgical masks are essential for halting airborne transmission, traditional masks don't have any inherent antibacterial qualities. In order to improve antibacterial activity, this work investigates the creation of herbal-coated surgical masks that integrate nutmeg (*Myristica fragrans*), mint (*Mentha* spp.), and acacia catechu into a polyvinyl alcohol (PVA) matrix. Through maceration extraction, the herbal extracts—which were abundant in bioactive substances including menthol, catechin, and carvacrol—were combined to create PVA, which was subsequently sprayed onto conventional surgical masks. In comparison to non-coated masks, the coated masks' antimicrobial efficacy was assessed using nutritional agar media, which showed a notable decrease in bacteria growth. Even antimicrobial coverage was ensured by a coating uniformity test that verified consistent deposition. The findings demonstrate how these herbal-coated masks can be used as an environmentally benign, biodegradable substitute for traditional antimicrobial coatings, thereby lowering medical waste and minimizing antimicrobial resistance (AMR). This innovative approach could enhance infection control in healthcare settings and daily public use, particularly against airborne diseases like COVID-19, influenza, and tuberculosis. Further research is recommended to optimize long-term stability, breathability, and scalability for widespread implementation.

INTRODUCTION

Any disease brought on by a microbe that spreads through the air is considered an airborne disorder.

Many clinically significant airborne infections are caused by a variety of pathogens, such as bacteria, viruses, and fungus.^[1] Any action that produces aerosolized particles, such as coughing, sneezing,

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Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.



talking, distributing dust, or spraying liquids, might spread these germs. It is crucial to understand that illnesses brought on by dust, smog, toxins, and air pollution are typically not considered airborne diseases. [2][3] The World Health Organization defines "airborne transmission of infectious agents" as the spread of disease-causing droplet nuclei that continue to be contagious after being suspended in the air for an extended period of time. Depending on whether it is spread by droplet nuclei or has several different channels of transmission, airborne transmission might be either favored or obligatory. [4] As an example, consider influenza, anthrax, chickenpox, adenovirus, enteroviruses, rotavirus, rhinovirus, streptococcus pneumoniae, measles, mumps, smallpox, tuberculosis, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome, and COVID-19. Only a few of the prevalent illnesses linked to airborne transmission are included in this non-exhaustive list. [5] Particular attention should be paid to COVID-19, the pandemic of the twenty-first century that is believed to spread by airborne routes, among other means. [6] There is still uncertainty about the function and geographic scope of these various mechanisms of transmission (contact, droplet spray, or aerosol inhalation) for particular respiratory illnesses, such as COVID-19 [7–11]. In order to prevent the exhalation of germs into the operating field, surgical masks are worn by healthcare professionals, mostly surgeons. There has been discussion recently about the use of face masks to prevent respiratory illnesses caused by airborne contamination [12–13]. An antimicrobial coating is used to reduce the possibility of infectious pathogens spreading through contaminated protective gear, such as masks. [14–16] The respiratory system is the main entry point for germs and viruses into the human body, however standard medical surgical masks are not efficient against these pathogens. They are

throwaway materials used only for filtration. Additionally, masks that are worn frequently may develop smells, discoloration, and degradation. [17] The survival of the human race is threatened by antimicrobial resistance (AMR). Rising rates of illness and mortality are caused by microbes that are resistant to common antimicrobials. These antimicrobials can be applied to surgical face masks to decrease microbial infections and lessen their environmental impact through reuse. A potential substitute for typical antimicrobials appears to be the easy integration of mint, acacia catachu, and nutmeg in an adhesive agent polyvinyl alcohol matrix. [18]

Mint

Two of the most popular fragrant herbs used in food and drink products are mint (*Mentha spp.*) and thyme (*Thymus spp.*) because of their flavor, scent, and therapeutic properties. These plants are members of the mint family (Lamiaceae), which includes numerous genera of well-known culinary and medicinal herbs, and the tribe Mentheae. The phenolics found in mint and thyme are examined in this review as prospective antibacterial medications and as natural phytochemicals that promote health. These compounds include pulegone, limonene, 1,8-cineole, p-cymene, carvone, menthol, menthone, carvacrol, thymol, and cinnamon aldehyde. [19].



Figure No.1: Mint [20]

Acacia catechu

The brown natural dye known as "cutch," "catechu," or "katha" is mostly made from the heartwood of *Acacia catechu*, which is present in the majority of the Indian sub-Himalayas (Anonymous, 1985). According to Anonymous (2006), catechin A, the main coloring agent found in cutch, has anti-inflammatory and anti-cancer properties and is employed in traditional remedies. *A. catechu* has anti-inflammatory and anti-cancer properties and is utilized in traditional treatments (Anonymous, 2006). To far, no research has been conducted to examine the antibacterial qualities of woolen yarn dyed with cutch that is both unmordanted and pre-mordanted. Therefore, in this investigation, the antimicrobial properties of dye were compared to opportunistic pathogenic yeasts, such as *Candida albicans* and *Candida tropicalis*, and common pathogenic bacteria, such as *Escherichia coli* and *Staphylococcus aureus*. [21]



Figure No. 2: *Acacia catechu* [22]

Nutmeg

Nutmeg belongs to the Myristicaceae family and the Magnoliales order (Figure 3). Two significant spices made from the fruit are mace and nutmeg. The tree's dark brown seed is called nutmeg. Nutmeg seeds exhibit significant antibacterial activity against a variety of pathogenic fungi and bacteria, both gram-positive and gram-negative. B-caryophyllene, a-pinene, b-pinene, p-cymene,

and carvacrol all contribute to antimicrobial action. [23]



Figure No.3: Nutmeg Seeds [23]

MATERIAL AND METHOD

Material Required:

Plant Materials:

- Mint (*Mentha spp.*) - The fresh leaves were gathered, cleaned.
 - Acacia catechu* (Khair) bark-Bark extract was sourced from reliable sources.
 - Nutmeg (*Myristica fragrans*) seeds-A fine powder was made from dried seeds.
- Solvent: Distilled water - used as a solvent in the extraction process of maceration.
 - Chemical Reagents: Polyvinyl Alcohol (PVA) – used in coatings as a binding polymer.
 - Mask substrate:

Surgical Masks – The foundation for the coating was a standard three-layered surgical mask.

Equipment's:

- Breakers – For the purpose of extraction and processing

- Filter paper –In order to eliminate particle matter
- Spray Bottle – For coating

Table no .1: Formula

Sr.no	Material Required	Quantity
1	Mint leaves	25 g
2	Acacia catechu bark	25 g
3	Nutmeg seeds powder	25 g
4	Distilled water	500 ml
5	Polyvinyl alcohol	5 g

Method

Method of Maceration Extraction

Step 1: Preparation of Plant Material

1) Mint Leaves

- Use distilled water to properly wash fresh mint leaves.
- Dry for three to five days at room temperature in the shade until the moisture content decreases.
- Using a blender or mortar and pestle, grind into a coarse powder.

2) Acacia Catechu Bark

- The bark should be broken up into little bits.
- Grind to a coarse powder after letting it dry at room temperature.

3) Nutmeg Seed

- Using a grinder, ground the nutmeg seeds into a fine powder.

Step 2: Maceration Process [24]

- 1) Weigh out 25 g of each plant powder individually.

- 2) Transfer the contents into a sanitized glass container.
- 3) Make sure all of the powder is submerged by pouring 100–200 milliliters of distilled water over the plant materials.
- 4) Seal the container to stop solvent loss and contamination.
- 5) Stir the mixture sometimes every 6 to 8 hours while it is kept at room temperature (25 to 30°C) for 24 to 72 hours.
- 6) After 72 hours, use muslin cloth and Whatman No. 1 filter paper to filter the mixture and get rid of any remaining plant material.
- 7) To create concentrate, use a water bath set at low temperatures (below 50°C) to concentrate the extract.

Method of coating surgical mask

Step 1: Preparation of Polyvinyl Alcohol (PVA) Solution [25]

- 1) 5 g of PVA should be dissolved in 100 mL of distilled water by heating it to 80°C while stirring constantly.
- 2) Stir until a uniform mixture is achieved.

Step 2 : Incorporation of Herbal Extracts into PVA Solution [26]

- 1) In a 1:1:1 ratio, combine the concentrated extracts of mint, nutmeg, and Acacia catechu.
- 2) Gradually add 5–10% (v/v) of the combined extract into the PVA solution.
- 3) Stir constantly to ensure even dispersion.

Step 3 : Coating Surgical Masks with Herbal-PVA Solution by using spray Method

- 1) The produced PVA-herbal extract solution was poured into a sterile spray bottle.
- 2) The surgical masks were set up in a sterile setting on a spotless, level surface.



- 3) A consistent coating was ensured by uniformly spraying the solution from a distance of 10 to 15 cm.
- 4) The coated masks were allowed to air dry for 15 to 20 minutes following spraying in order to allow the first solvent to evaporate
- 5) The masks were further dried in a hot air oven set at 40°C for two hours to guarantee thorough drying and adhesion.
- 6) The dried masks were kept for additional testing and characterisation in a sterile, airtight container.

According to the study's findings, surgical masks coated with herbs are more effective than those that aren't in lowering the chance of contracting infection from airborne illnesses.

Antimicrobial Testing Using Nutrient Agar Media:

Conducting antimicrobial testing on surgical masks coated with herbs and comparing the findings to control (non-coated surgical masks) in order to assess the efficacy of the herbal coating

RESULT AND DISCUSSION

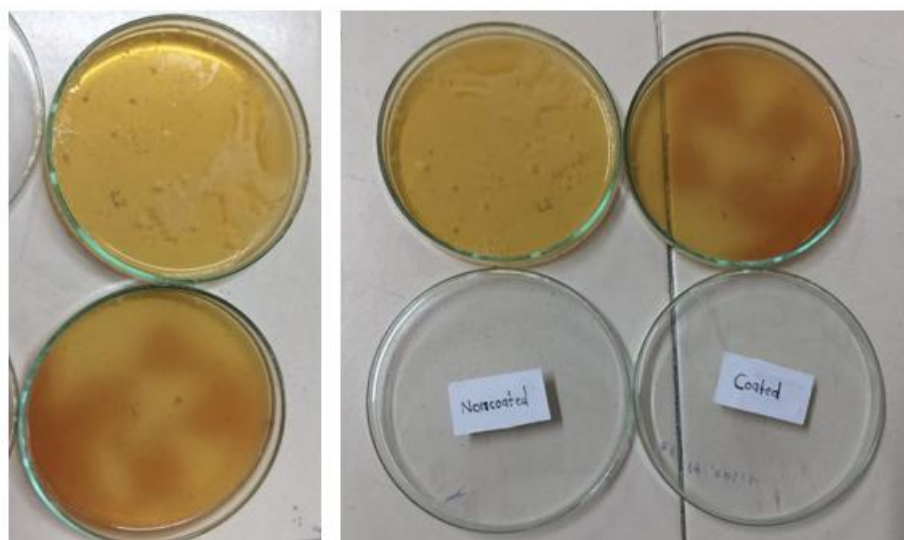


Figure No.4: Antimicrobial Test

Table No. 2: Observation table for Herbal Antimicrobial Testing

Sr. No	Parameters	Non-Coated (Control) Sample	Coated Sample
1	Bacterial growth	High (9/10)	Low (3/10)
2	Opacity	Cloudy (8/10)	Clearer (4/10)

3	Colour change	Yellowish (7/10)	Lighter brown (4/10)
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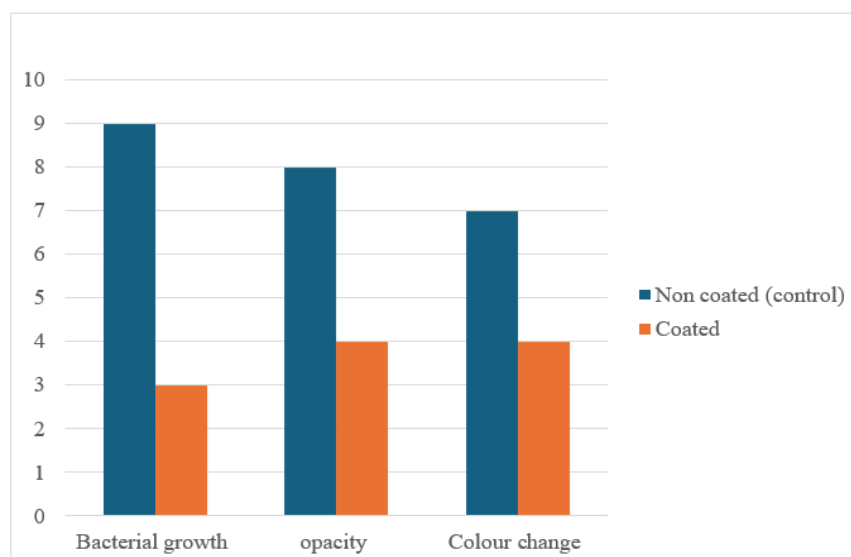


Figure No. 5: Graphical Representation of Herbal Antimicrobial Testing

1. Significant Reduction in Bacterial Growth:

Because of the antimicrobial ingredient, the coated sample has reduced bacterial growth, but the noncoated sample exhibits noticeably increased bacterial growth. The antibacterial qualities of mint, nutmeg, and Acacia catechu are confirmed by the decreased bacterial growth in the coated sample containing herbal extracts.

2. Medium Opacity: The noncoated sample is more turbid, which suggests that bacteria are growing. The clearer coated sample indicates that microbial activity has been inhibited.

3. Color Change: The darker yellow color of the uncoated sample indicates bacterial metabolic byproducts. Because the coated sample changes color less, there is less bacterial activity.

Table No. 3: Aqueous Extracts Inhibition Zone in Diameter on Human Pathogens on Agar Diffusion Method

Scientific names	$\mu\text{g/ml}$	Inhibition zone in diameter (mm)						
		Gram positive bacteria			Gram negative bacteria		Fungi	
		S. pne	S. aureus	S. pyrogen	E.coli	H. influenza	A.niger	C.albicans
<i>Mentha spp</i>	30	27(0.7)	27(0.2)	28(1.2)	22(0.7)	23(0.2)	23(0.7)	10(0.2)
	10	16(0.3)	17(0.2)	19(0.8)	10(0.2)	14(1.3)	12(1.0)	-
<i>Acacia catechu</i>	30	25(1.0)	26(2.2)	27(1.1)	14(0.2)	13(0.3)	-	24(0.5)
	10	16(0.6)	16(0.5)	17(1.0)	-	-	-	11(0.7)
<i>Myristic afragrans</i>	30	28(1.6)	28(2.6)	27(0.6)	23(0.2)	22(0.2)	22(0.2)	22(0.3)
	10	18(0.2)	17(1.1)	18(1.1)	7(0.5)	11(0.1)	-	10(0.2)

The values represent mean (standard deviation), NT = Not tested, — = No inhibition zone, C.a = *Candida albicans*, A.n = *Aspergillus niger*, E. coli = *Escherichia coli*, H.I = *Haemophilus influenzae*,

S.pne = *Streptococcus pneumoniae*, S.a = *Staphylococcus aureus*, S.p = *Streptococcus pyogenes*. Where, #P < 0.05, ##P < 0.01 when compared to modern drug-treated S.

pneumoniae. $P < 0.01$ when compared to modern drug-treated *E. coli*. * $P < 0.05$, ¥** $P < 0.01$, $P < 0.05$, ¥¥** Aqueous herbal extracts from *Myristica fragrans*, *Acacia catechu*, and *Mentha* spp. were evaluated for their antibacterial and antifungal qualities against a variety of gram-positive and gram-negative bacteria and fungi using the agar diffusion technique. Inhibition zones at doses of 10 µg/ml and 30 µg/ml were measured in millimeters. *Mentha* species exhibited potent antibacterial action, especially at 30 µg/ml, with inhibition zones that ranged from 28.0 mm for *S. pyogenes* to 22.0 mm for *E. coli*. At this concentration, there was also noticeable antifungal action, particularly against *Aspergillus niger* (23.0 mm) and *Candida albicans* (10.0 mm). Inhibition zones for *Acacia catechu* ranged from 13.0 mm (*H. influenzae*) to 27.1 mm (*S. pyogenes*) at 30 µg/ml, indicating moderate activity. With a zone of 24.0 mm, antifungal activity against *Candida albicans* was observed at the higher concentration. The antibacterial properties of *Myristica fragrans* were strong at 30 µg/ml, particularly against *S. pneumoniae* (28.1 mm) and *S. aureus* (28.6 mm). It has a modest antifungal action against *Candida albicans* at 10 µg/ml, with a zone of 10.0 mm. The results validate the potential for these extracts to lower microbial contamination when applied as herbal coatings on surgical masks. Their antifungal properties and broad-spectrum activity highlight the potential of employing these natural compounds to expand their protective function and improve mask hygiene. These coatings could be used as a sustainable, efficient substitute or

addition to synthetic antibacterial agents in personal protective equipment.

a. Coating Uniformity Test

Visual inspection was used to assess the homogeneity of the herbal coating applied by spray technique to surgical masks. The findings showed that the herbal extracts adhered to the mask surface in an even and uniform layer.

1. Visual Inspection:

There were no obvious clumps or streaks on the coated masks, which showed a consistent appearance. Herbal extract deposition was confirmed by the slightly stained surface caused by the natural pigments from mint (*Mentha* spp.), nutmeg (*Myristica fragrans*), and acacia catechu. Herbal extracts must be evenly coated to maintain their antibacterial qualities and long-term efficacy. A regulated application was made possible by the spray approach, which avoided uneven distribution or excessive accumulation. A synergistic herbal layer was created by combining the cooling and antibacterial qualities of mint with the astringent effects of *Acacia catechu* and the antifungal capabilities of nutmeg. As an alternative to traditional antimicrobial treatments, the findings of the uniformity test confirm the potential of this herbal-coated mask. This formulation could be optimized for commercial and medical purposes with more research on antibacterial activity over time.





Figure No. 6: Herbal Coated Surgical Mask

CONCLUSION

This study demonstrates how herbal-coated surgical masks can be a useful substitute for traditional masks in terms of lowering microbial contamination and enhancing antimicrobial protection. The study effectively created a mask with enhanced antibacterial qualities by combining natural antimicrobial agents—Mint (*Mentha spp.*), Acacia catechu, and Nutmeg (*Myristica fragrans*)—into a polyvinyl alcohol (PVA) matrix. The microbial growth on the herbal-coated masks was significantly lower than that on the non-coated masks, according to antimicrobial testing using nutrient agar media. Gram-positive and gram-negative bacteria as well as opportunistic fungi that cause respiratory infections can be effectively combatted by the coated masks' antibacterial, antifungal, and antiviral qualities, which were enhanced by the presence of bioactive substances like menthol, catechin, and carvacrol. The coating uniformity test verified that the herbal extracts were distributed evenly and consistently, guaranteeing their appropriate adherence and antibacterial efficacy. The application of polyvinyl alcohol (PVA) as a binding agent avoided flaking and guaranteed long-lasting protection, while the spray

coating technique produced a consistent layer. These plant-based extracts, as opposed to synthetic antimicrobial agents, provide an environmentally friendly and biodegradable alternative that lowers the danger of antimicrobial resistance (AMR) and may even enable mask reuse, which would reduce medical waste. The results imply that surgical masks coated with herbs may find useful uses in medical facilities, pandemic preparedness, and everyday general use, especially in preventing airborne illnesses like COVID-19, influenza, and tuberculosis. To guarantee these masks' efficacy and comfort throughout time, more investigation is required to evaluate their long-term stability, breathability, and viability for mass manufacture. These masks may be a sustainable, safe, and efficient substitute for conventional antimicrobial coatings with further research and clinical validation, supporting efforts to prevent infections and promote public health.

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HOW TO CITE: Snehal Sonar, Dr. Vivek Paithankar*, Shreya Bankar, Trupti Nimburkar, Design and Optimization of 'Green Guard' Biodegradable Face Masks Incorporating Herbal Extracts for Antimicrobial Properties, *Int. J. of Pharm. Sci.*, 2025, Vol 3, Issue 6, 1081-1091. <https://doi.org/10.5281/zenodo.15605625>

