

DEVELOPMENT AND EVALUATION OF PLANT-BASED ANTIMICROBIAL SURFACE COATINGS FOR CONTROLLING BACTERIAL CONTAMINATION IN LABORATORIES AND PUBLIC FACILITIES IN POLYTECHNICS IN SOUTH-WEST NIGERIA

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Article Info

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Abstract

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Development and Evaluation of Plant-Based Antimicrobial Surface Coatings for Controlling Bacterial Contamination in Laboratories and Public Facilities in Polytechnics in South-West Nigeria

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High-touch surfaces in shared institutional settings are repeatedly recontaminated despite routine cleaning. This study developed and evaluated plant-based antimicrobial surface coatings from indigenous plant extracts for laboratories and public facilities in polytechnics in South-West Nigeria. An experimental laboratory design combined extraction, formulation and microbiological evaluation. Aqueous and ethanolic extracts of five indigenous plants were screened against *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa*, and the most active were formulated into chitosan-based coatings. *Ocimum gratissimum* and *Azadirachta indica* showed the highest activity, with minimum inhibitory concentrations of 1.25 to 5.0 mg/mL. A 5% (w/v) *O. gratissimum* coating achieved a 3.8 log₁₀ reduction against *S. aureus* and a 3.2 log₁₀ reduction against *E. coli* within 4 hours of contact. Coated surfaces retained activity after 20 wiping cycles (2.6 log₁₀ reduction) and after 30 days of ageing (2.1 log₁₀ reduction). Preliminary cytotoxicity screening indicated no significant toxicity at the active concentrations (82.4% cell viability). Plant-based coatings from indigenous extracts offer a natural, low-cost and durable means of suppressing surface contamination in Nigerian polytechnics, and the study provides validated formulations for wider adoption.

Keywords: plant-based antimicrobials; surface coatings; chitosan; indigenous plants; bacterial contamination; Nigeria

Introduction

Surfaces contaminated with bacteria are an important route for the transmission of infection, and in shared institutional environments such as polytechnic laboratories and public facilities, high-touch surfaces are repeatedly recontaminated despite routine cleaning. Conventional disinfection is fast-acting but impermanent, so contamination returns quickly between cleanings, sustaining a reservoir of pathogens and, increasingly, of antimicrobial-resistant organisms (Mouhoub et al., 2023a). Research has documented that high-touch surfaces in institutional settings, including door handles, laboratory benches, and shared equipment, harbour bacterial pathogens even after routine cleaning, with studies from tertiary institutions in Nigeria identifying significant contamination on frequently touched surfaces. Studies have found that contamination of high-touch surfaces in hospital and laboratory environments contributes to the

transmission of healthcare-associated infections, with surfaces serving as reservoirs that can be recontaminated rapidly after cleaning. Durable, self-sanitising surfaces that suppress contamination between cleanings therefore offer a valuable complement to conventional hygiene, addressing the gap between periodic cleaning and continuous contamination risk.

Plant-derived compounds are well recognised as natural antibacterial agents. A large literature demonstrates that extracts and essential oils from medicinal plants, rich in phytochemicals such as alkaloids, flavonoids, tannins and phenolics, inhibit a broad range of bacteria by disrupting membranes and interfering with essential cellular processes (Abdoulahi et al., 2023). Studies have identified multiple mechanisms of antibacterial action for plant-derived compounds, including disruption of cell membrane integrity, inhibition of nucleic acid synthesis, inhibition of energy metabolism, and interference with cell wall synthesis. These natural agents offer a biodegradable, relatively low-toxicity alternative to synthetic biocides and are less prone to driving resistance because of their multi-target action. Research has demonstrated that the complex mixtures of phytochemicals found in plant extracts exhibit synergistic antibacterial effects, making it more difficult for bacteria to develop resistance compared with single-target synthetic antibiotics. Nigerian medicinal plants have been extensively documented for their antibacterial properties, with studies identifying numerous species with significant activity against clinically relevant bacteria.

Incorporating such extracts into surface coatings turns their antibacterial activity into a durable, contact-active barrier. Studies show that plant extracts and essential oils formulated into biopolymer matrices such as chitosan produce coatings and films with strong antibacterial and antiadhesion activity against foodborne and environmental bacteria, and that formulation governs both efficacy and the physical properties of the coating (Mouhoub et al., 2023b; Casalini & Giacinti Baschetti, 2023). Research on chitosan-based coatings has demonstrated that the incorporation of essential oils improves antibacterial activity while maintaining film integrity, with studies showing significant reductions in bacterial adhesion and viability on coated surfaces. Chitosan itself possesses intrinsic antibacterial properties, attributed to its positively charged amino groups interacting with negatively charged bacterial cell membranes, causing membrane disruption and cell death. The combination of chitosan with plant extracts creates a dual-action coating that combines the intrinsic antibacterial properties of the biopolymer with the additional activity of the incorporated phytochemicals. Coatings incorporating natural actives such as carvacrol have been shown to suppress microbial growth on treated surfaces (Shu et al., 2024). Studies have also demonstrated the use of other biopolymers, including cellulose derivatives and pectin, for developing antimicrobial coatings with plant extracts, though chitosan remains the most extensively studied due to its unique combination of properties.

Despite this promise, the development and rigorous evaluation of plant-based antimicrobial coatings using indigenous Nigerian plants, tailored to institutional surfaces and low-cost fabrication, remains limited. Much of the evidence concerns food packaging or uses imported actives, with little work translating locally available plant extracts into validated coatings for laboratory and public-facility surfaces in the South-West (Casalini & Giacinti Baschetti, 2023).

Research on antimicrobial coatings in Nigeria has focused primarily on food applications or has used imported essential oils rather than locally available plant materials. This study addresses that gap by developing and evaluating plant-based antimicrobial coatings from indigenous extracts for controlling surface contamination in polytechnics.

Statement of the Problem

Laboratories and public facilities in South-West polytechnics contain high-touch surfaces that are persistent reservoirs of bacterial contamination, and routine cleaning does not durably control them. Because conventional disinfection is impermanent, surfaces are rapidly recontaminated between cleanings, sustaining the transmission of pathogens and of antimicrobial-resistant organisms in busy shared environments (Mouhoub et al., 2023a). The difficulty is that affordable, durable, self-sanitising surface treatments suited to these settings are not available or validated locally, even though indigenous plants offer abundant, low-cost antibacterial agents that could be formulated into such coatings (Abdoulahi et al., 2023). Without a proven plant-based coating and evidence of its efficacy, durability and safety, institutions lack a practical means of suppressing surface contamination beyond the transient effect of cleaning (Casalini & Giacinti Baschetti, 2023). The opportunity to improve surface hygiene sustainably therefore remains unrealised.

The specific challenges facing Nigerian polytechnics are situated within a broader context of surface contamination in institutional settings. Studies from Nigerian tertiary institutions have documented significant bacterial contamination on frequently touched surfaces, including laboratory benches, door handles, and shared equipment. Research has identified that contamination of surfaces in educational settings contributes to the transmission of infectious diseases, with students and staff at risk of exposure to pathogenic bacteria. The emergence of antimicrobial-resistant organisms on these surfaces compounds the problem, as infections acquired from contaminated surfaces may be difficult to treat. The limitations of conventional disinfection are well documented, with studies showing that bacterial contamination can return to pre-cleaning levels within hours of disinfection, particularly on high-touch surfaces. The use of synthetic biocides also raises concerns about environmental impact and the potential for resistance development, motivating interest in natural alternatives. These findings underscore the need for durable, natural antimicrobial coatings tailored to institutional settings in Nigeria.

Durable plant-based antimicrobial coatings promise to suppress surface contamination between cleanings, reducing transmission of pathogens and resistant organisms, and to do so using freely available indigenous plants rather than costly imported biocides (Mouhoub et al., 2023b; Shu et al., 2024). Situated in polytechnics, the work also builds capacity and has enterprise potential, since students and technicians learn extraction, formulation and microbiological evaluation. By screening extracts, formulating coatings and rigorously evaluating them, the study produces a validated, low-cost solution and dataset that are immediately actionable. The beneficiaries are substantial: institutions gain better, more durable surface hygiene; students and staff gain reduced infection risk and hands-on capability; and the environment benefits from

natural, biodegradable actives. This study addresses that gap by developing and rigorously evaluating plant-based coatings from indigenous extracts for surface contamination control in South-West polytechnics.

Aim and Objectives

Aim: To develop and evaluate plant-based antimicrobial surface coatings from indigenous plant extracts for controlling bacterial contamination in laboratories and public facilities in polytechnics in South-West Nigeria.

Specific Objectives:

- i. To extract and screen selected indigenous plant materials for antibacterial activity and phytochemical constituents;
- ii. To formulate the most active extracts into surface coatings and characterise them;
- iii. To evaluate the antibacterial efficacy of the coatings against target bacteria on representative surfaces;
- iv. To assess the durability and safety of the coatings under use-relevant conditions; and
- v. To establish validated coating formulations and recommendations for institutional surface hygiene.

Research Questions

1. What is the antibacterial activity and phytochemical composition of selected indigenous plant extracts?
2. How can the most active extracts be formulated into surface coatings, and what are the physical and adhesion properties of the coatings?
3. What is the antibacterial efficacy of the coatings against target bacteria on representative surfaces?
4. What is the durability and safety of the coatings under use-relevant conditions?

5. What validated coating formulations and recommendations can be established for institutional surface hygiene?

Literature Review

The persistence of bacterial contamination on surfaces, and the impermanence of conventional disinfection, have motivated research into durable antimicrobial surfaces. Studies note that fast-acting liquid disinfection does not prevent rapid recontamination, so surfaces remain reservoirs of pathogens between cleanings, and that antiadhesion and self-sanitising coatings address this gap (Mouhoub et al., 2023a). Research has documented that bacterial contamination on high-touch surfaces can return to pre-cleaning levels within hours, with studies showing that surfaces in hospital and laboratory environments are frequently contaminated with pathogenic bacteria. Studies from Nigerian tertiary institutions have identified bacterial contamination on frequently touched surfaces, including laboratory benches and door handles, with isolates including *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*. This frames durable coatings as a valuable complement to routine hygiene.

A large literature establishes the antibacterial activity of plant-derived compounds. Extracts and essential oils rich in phytochemicals inhibit diverse bacteria through membrane disruption and interference with cellular processes, offering biodegradable, low-toxicity agents whose multi-target action reduces the likelihood of resistance (Abdoulahi et al., 2023). Studies have identified multiple mechanisms of antibacterial action for plant-derived compounds, including disruption of cell membrane integrity, inhibition of nucleic acid synthesis, inhibition of energy metabolism, and interference with cell wall synthesis. The complex mixtures of phytochemicals found in plant extracts exhibit synergistic antibacterial effects, making it more difficult for bacteria to develop resistance compared with single-target synthetic antibiotics. Nigerian medicinal plants have been extensively documented for their antibacterial properties, with studies identifying numerous species with significant activity against clinically relevant bacteria. This body of work supplies the active agents on which plant-based coatings depend.

A third strand concerns the formulation of these actives into films and coatings. Research incorporating essential oils and extracts into biopolymer matrices such as chitosan demonstrates strong antibacterial and antiadhesion activity and shows that formulation determines both efficacy and physical properties, establishing the feasibility of durable natural coatings (Mouhoub et al., 2023b; Casalini & Giacinti Baschetti, 2023). Studies have demonstrated that chitosan-based coatings incorporating essential oils show significant reductions in bacterial adhesion and viability on coated surfaces. Research has shown that the incorporation of plant extracts into chitosan films improves antibacterial activity while maintaining film integrity, with the optimal concentration depending on the specific extract and target bacteria. Chitosan itself possesses intrinsic antibacterial properties, attributed to its positively charged amino groups interacting with negatively charged bacterial cell membranes, causing membrane disruption and cell death. The

combination of chitosan with plant extracts creates a dual-action coating that combines the intrinsic antibacterial properties of the biopolymer with the additional activity of the incorporated phytochemicals. This literature underpins the formulation approach adopted here.

A fourth strand provides direct evidence of surface-active coatings. Studies applying coatings incorporating natural actives such as carvacrol to surfaces demonstrate measurable suppression of microbial growth, confirming that plant-based coatings can control contamination in practice rather than only in extract-level assays (Shu et al., 2024). Research has demonstrated that chitosan coatings incorporated with carvacrol improve postharvest quality of fruits by suppressing microbial growth, with the coating forming a protective barrier that reduces contamination. Studies have also evaluated the durability of antimicrobial coatings, with research showing that activity can be retained after multiple wiping cycles and extended periods of use. These works validate the surface-evaluation strategy of the study.

Across these strands a consistent gap emerges. Much of the evidence concerns food packaging or uses imported actives, with limited work translating indigenous Nigerian plant extracts into validated antimicrobial coatings for institutional laboratory and public-facility surfaces (Casalini & Giacinti Baschetti, 2023). Research on antimicrobial coatings in Nigeria has focused primarily on food applications or has used imported essential oils rather than locally available plant materials. Moreover, few studies have systematically evaluated the durability and safety of plant-based coatings under use-relevant conditions for institutional settings. This study addresses that gap by developing and rigorously evaluating plant-based coatings from indigenous extracts for surface contamination control in South-West polytechnics.

Methods

The study adopted an experimental laboratory design combining extraction, formulation and microbiological evaluation. Selected indigenous plant materials were chosen for documented antibacterial use, including *Ocimum gratissimum* (scent leaf), *Azadirachta indica* (neem), *Moringa oleifera* (moringa), *Alchornea cordifolia* (Christmas bush), and *Psidium guajava* (guava). These plants were selected based on ethnobotanical documentation of their antibacterial properties in Nigerian traditional medicine. Plant materials were collected from Osun State, identified by a botanist, and voucher specimens deposited in the herbarium. The plant materials were dried at room temperature, ground to powder, and extracted using ethanol, methanol, and water by maceration (72 hours) and Soxhlet extraction. Solvents were removed using a rotary evaporator, and the crude extracts were stored at 4°C until use.

Phytochemical screening and quantification of key constituents were performed by standard colorimetric and spectrophotometric methods, including tests for alkaloids (Dragendorff's reagent), flavonoids (aluminium chloride colorimetric method), tannins (Folin-Ciocalteu method), saponins (foam test), and total phenolics (Folin-Ciocalteu method). The antibacterial activity of the extracts was determined against target bacteria, including *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923), *Klebsiella pneumoniae* (ATCC 13883), and *Pseudomonas*

aeruginosa (ATCC 27853), using agar-well diffusion and minimum inhibitory concentration (MIC) assays. The MIC was determined by broth microdilution method in 96-well plates, with bacterial growth assessed by optical density at 600 nm.

The most active extracts were then formulated into surface coatings within a chitosan matrix. Chitosan (2% w/v) was dissolved in 1% acetic acid, and plant extracts were incorporated at concentrations of 2.5%, 5%, and 10% (w/v). The coatings were characterised for physical properties, including thickness (digital micrometer), adhesion (ASTM D3359 cross-hatch test), and water contact angle (goniometer). Antibacterial efficacy was evaluated by applying the coatings to representative surface coupons (stainless steel and glass), challenging them with defined bacterial suspensions (10^6 CFU/mL), and quantifying viable-count reduction over time (0, 1, 2, 4, 8, 24 hours) relative to uncoated controls. Durability was assessed through repeated challenge, wiping (20, 40, 60 cycles with damp cloth), and ageing (30, 60, 90 days at ambient temperature). Preliminary safety was evaluated through cytotoxicity screening against human dermal fibroblasts (MTT assay) at concentrations corresponding to the active coating formulations.

Data were analysed using descriptive statistics and appropriate inferential tests (ANOVA with post-hoc Tukey test) to compare extracts, formulations and controls and to identify optimal coatings. All work was conducted under strict biosafety and quality-control procedures, including sterile technique, appropriate controls, and institutional clearance from the relevant ethics and biosafety committees.

Results

The study successfully developed and evaluated plant-based antimicrobial surface coatings. The findings are organised below according to the five research questions.

Research Question 1: What is the antibacterial activity and phytochemical composition of selected indigenous plant extracts?

Table 1: *Phytochemical Composition of Plant Extracts*

Phytochemical	<i>O. gratissimum</i>	<i>A. indica</i>	<i>M. oleifera</i>	<i>A. cordifolia</i>	<i>P. guajava</i>
Alkaloids	+++	+++	++	+++	++
Flavonoids	+++	+++	+++	+++	+++
Tannins	+++	++	+	+++	+++
Saponins	++	+	+++	++	+
Total phenolics (mg GAE/g)	142.6	128.4	96.8	118.2	134.5

Note. +++ = strongly present; ++ = moderately present; + = weakly present.

Table 2: Antibacterial Activity of Plant Extracts (Zone of Inhibition in mm)

Plant Extract	<i>E. coli</i>	<i>S. aureus</i>	<i>K. pneumoniae</i>	<i>P. aeruginosa</i>
<i>O. gratissimum</i>	20.2 (1.2)	22.4 (1.4)	18.6 (1.0)	16.8 (1.2)
<i>A. indica</i>	20.8 (1.3)	19.2 (1.2)	17.4 (1.1)	15.6 (1.0)
<i>M. oleifera</i>	16.4 (1.0)	15.8 (1.1)	14.2 (0.9)	13.4 (0.8)
<i>A. cordifolia</i>	18.6 (1.1)	17.4 (1.0)	16.2 (0.9)	14.8 (1.0)
<i>P. guajava</i>	17.2 (1.0)	18.6 (1.2)	15.4 (0.9)	14.2 (0.8)
Gentamicin (control)	24.6 (1.4)	26.2 (1.5)	22.8 (1.3)	20.4 (1.2)

Table 3: Minimum Inhibitory Concentrations (MIC) of Most Active Extracts

Plant Extract	<i>E. coli</i> (mg/mL)	<i>S. aureus</i> (mg/mL)	<i>K. pneumoniae</i> (mg/mL)	<i>P. aeruginosa</i> (mg/mL)
<i>O. gratissimum</i>	2.5	1.25	5.0	5.0
<i>A. indica</i>	2.5	2.5	5.0	5.0

Table 1 presents the phytochemical composition of plant extracts. All extracts contained alkaloids, flavonoids, tannins, saponins and phenolics, with variations in the strength of detection. *O. gratissimum* had the highest total phenolic content (142.6 mg GAE/g), followed by *P. guajava* (134.5 mg GAE/g) and *A. indica* (128.4 mg GAE/g). The presence of these phytochemicals is consistent with the literature on plant-derived antibacterial compounds, which has identified these classes of compounds as responsible for antibacterial activity (Abdoulahi et al., 2023). Table 2 presents the antibacterial activity of plant extracts. *O. gratissimum* showed the highest activity against *S. aureus* (22.4 mm), while *A. indica* showed the highest activity against *E. coli* (20.8 mm). Both extracts showed moderate activity against *K. pneumoniae* and *P. aeruginosa*. The zone of inhibition values were lower than the gentamicin control (24.6–26.2 mm) but still indicate significant antibacterial activity. Table 3 presents the MIC values. *O. gratissimum* had MICs of 1.25 mg/mL against *S. aureus* and 2.5 mg/mL against *E. coli*, while *A. indica* had MICs of 2.5 mg/mL against both organisms. These MIC values are consistent with the literature on Nigerian medicinal plants, which has reported MICs ranging from 0.5 to 10 mg/mL for active extracts. The activity of *O. gratissimum* against *S. aureus* is particularly notable, as this organism is a common cause of skin and soft tissue infections and is frequently found on contaminated surfaces.

Research Question 2: How can the most active extracts be formulated into surface coatings, and what are the physical and adhesion properties of the coatings?

Table 4: Physical Properties of Chitosan-Based Coatings

Coating Formulation	Thickness (µm)	Adhesion (ASTM D3359)	Water Contact Angle (°)
Chitosan only	42.6 (2.4)	4B	68.4 (3.2)
Chitosan + <i>O. gratissimum</i> 2.5%	48.2 (2.6)	4B	72.6 (3.4)
Chitosan + <i>O. gratissimum</i> 5%	52.4 (2.8)	4B	78.2 (3.6)
Chitosan + <i>O. gratissimum</i> 10%	58.6 (3.2)	3B	84.6 (4.2)
Chitosan + <i>A. indica</i> 5%	51.8 (2.6)	4B	76.4 (3.4)

Note. Adhesion: 5B = 0% coating removed; 4B = <5% removed; 3B = 5-15% removed.

Table 4 presents the physical properties of the chitosan-based coatings. Coating thickness increased with extract concentration, from 42.6 µm (chitosan only) to 58.6 µm (10% extract). Adhesion was rated as 4B for most formulations, indicating excellent adhesion with less than 5% coating removed, while the 10% extract formulation had slightly lower adhesion (3B). Water contact angle increased with extract concentration, from 68.4° (chitosan only) to 84.6° (10% extract), indicating increased hydrophobicity that may reduce bacterial adhesion. The physical properties are consistent with the literature on chitosan-based coatings, which has reported thicknesses in the range of 30–100 µm and contact angles of 60–90° depending on formulation. The excellent adhesion (4B) indicates that the coatings are suitable for application to institutional surfaces. The increased hydrophobicity with extract incorporation is consistent with the literature, which has shown that essential oils can increase the hydrophobicity of chitosan films.

Research Question 3: What is the antibacterial efficacy of the coatings against target bacteria on representative surfaces?

Table 5: Antibacterial Efficacy of Coatings on Surface Coupons ($\log_{10}$ Reduction)

Coating Formulation	<i>S. aureus</i> (4h)	<i>E. coli</i> (4h)	<i>K. pneumoniae</i> (4h)	<i>P. aeruginosa</i> (4h)
Chitosan only	1.8 (0.2)	1.4 (0.2)	1.2 (0.1)	1.0 (0.1)
Chitosan + <i>O. gratissimum</i> 2.5%	2.6 (0.3)	2.2 (0.2)	1.8 (0.2)	1.6 (0.2)
Chitosan + <i>O. gratissimum</i> 5%	3.8 (0.3)	3.2 (0.3)	2.8 (0.2)	2.4 (0.2)
Chitosan + <i>O. gratissimum</i> 10%	4.2 (0.4)	3.6 (0.3)	3.2 (0.3)	2.8 (0.3)

Coating Formulation	<i>S. aureus</i> (4h)	<i>E. coli</i> (4h)	<i>K. pneumoniae</i> (4h)	<i>P. aeruginosa</i> (4h)
Chitosan + <i>A. indica</i> 5%	3.4 (0.3)	3.6 (0.3)	2.6 (0.2)	2.2 (0.2)

Table 5 presents the antibacterial efficacy of the coatings on surface coupons. Chitosan coatings incorporating *O. gratissimum* extract at 5% (w/v) achieved a 3.8 log₁₀ reduction against *S. aureus* and a 3.2 log₁₀ reduction against *E. coli* within 4 hours of contact, representing a significant improvement over chitosan-only coatings (1.8 and 1.4 log₁₀, respectively). The 10% extract formulation achieved slightly higher reductions (4.2 and 3.6 log₁₀), but this was accompanied by reduced adhesion properties (3B rating), indicating a trade-off between efficacy and physical durability. The *A. indica* 5% formulation achieved a 3.4 log₁₀ reduction against *S. aureus* and a 3.6 log₁₀ reduction against *E. coli*, demonstrating efficacy comparable to the *O. gratissimum* formulation. The log₁₀ reductions observed in this study are consistent with the literature on antimicrobial coatings, which has reported reductions of 2–5 log₁₀ depending on the active agent and formulation. The 5% *O. gratissimum* formulation was selected as optimal, achieving high efficacy while maintaining excellent adhesion properties. These findings confirm that plant-based coatings can effectively control bacterial contamination on surfaces, consistent with the literature on chitosan-based coatings incorporating plant extracts.

Research Question 4: What is the durability and safety of the coatings under use-relevant conditions?

Table 6: *Durability of Coatings Under Use-Relevant Conditions*

Condition	<i>S. aureus</i> Log ₁₀ Reduction	<i>E. coli</i> Log ₁₀ Reduction
Initial (0 cycles)	3.8 (0.3)	3.2 (0.3)
After 20 wiping cycles	2.6 (0.2)	2.2 (0.2)
After 40 wiping cycles	1.8 (0.2)	1.4 (0.2)
After 60 wiping cycles	1.2 (0.1)	0.8 (0.1)
After 30 days ageing	2.1 (0.2)	1.8 (0.2)
After 60 days ageing	1.6 (0.2)	1.2 (0.1)
After 90 days ageing	1.0 (0.1)	0.8 (0.1)

Table 7: Cytotoxicity Screening of Coating Formulations (MTT Assay)

Formulation	Cell Viability (%)
Control (untreated)	100
Chitosan only	92.4 (4.2)
Chitosan + <i>O. gratissimum</i> 2.5%	88.6 (4.6)
Chitosan + <i>O. gratissimum</i> 5%	82.4 (4.8)
Chitosan + <i>O. gratissimum</i> 10%	74.2 (5.2)
Chitosan + <i>A. indica</i> 5%	84.6 (4.4)

Table 6 presents the durability of coatings under use-relevant conditions. The coated surfaces retained antibacterial activity after 20 wiping cycles, with a mean viable-count reduction of 2.6 log₁₀ against *S. aureus* and 2.2 log₁₀ against *E. coli*. Activity declined with further wiping, with reductions of 1.2 and 0.8 log₁₀ after 60 cycles. Ageing also reduced activity, with a mean reduction of 2.1 log₁₀ after 30 days and 1.0 log₁₀ after 90 days. The durability results are consistent with the literature on antimicrobial coatings, which has reported activity retention for 20–50 wiping cycles depending on the formulation. The retention of activity after 20 wiping cycles (2.6 log₁₀) indicates that the coating would provide effective antibacterial activity between routine cleanings, supporting its use as a complement to conventional disinfection. Table 7 presents the cytotoxicity screening results. The 5% *O. gratissimum* formulation showed 82.4% cell viability, indicating low cytotoxicity. The 10% formulation showed higher cytotoxicity (74.2% viability), consistent with the higher concentration of active compounds. The 5% formulation was selected as optimal, balancing efficacy and safety. The low cytotoxicity of the 5% formulation is consistent with the literature on plant-based antimicrobials, which are generally considered safe for topical applications at appropriate concentrations.

Research Question 5: What validated coating formulations and recommendations can be established for institutional surface hygiene?

Based on the findings of this study, the validated coating formulation for institutional surface hygiene is chitosan (2% w/v) incorporating *O. gratissimum* extract at 5% (w/v). This formulation achieved the best balance of antibacterial efficacy (3.8 log₁₀ reduction against *S. aureus*), physical durability (4B adhesion, activity retained after 20 wiping cycles), and safety (82.4% cell viability). Recommendations for institutional surface hygiene include:

Short-term interventions (0–6 months): (1) Apply the validated coating to high-touch surfaces in laboratories and public facilities, including door handles, laboratory benches, and shared equipment; (2) Conduct training for cleaning staff on coating application and maintenance; (3) Monitor coating performance through periodic surface sampling and bacterial counts; (4)

Establish a re-application schedule based on durability findings (approximately every 3–4 weeks); and (5) Develop standard operating procedures for coating application and maintenance.

Medium-term interventions (6–24 months): (1) Establish a small-scale production facility for coating formulation and distribution within the institution; (2) Conduct field trials across multiple buildings to evaluate real-world performance; (3) Develop partnerships with local plant suppliers to ensure sustainable sourcing of *O. gratissimum*; (4) Conduct cost-benefit analysis of coating application versus conventional disinfection; and (5) Explore the potential for commercialisation and enterprise development.

Long-term approaches (2–5 years): (1) Develop a national framework for antimicrobial surface coatings in tertiary institutions; (2) Support research on additional plant species and formulations; (3) Establish quality standards and testing protocols for plant-based antimicrobial coatings; (4) Build capacity for local production and commercialisation of the coatings; and (5) Advocate for policy support for natural, sustainable surface hygiene solutions in institutional settings.

Discussion

The central finding of this study is the demonstration that plant-based antimicrobial coatings from indigenous plant extracts can effectively control bacterial contamination on surfaces in laboratory and public facility settings, with the optimal formulation achieving a 3.8 log₁₀ reduction against *S. aureus* and a 3.2 log₁₀ reduction against *E. coli* within 4 hours of contact. These findings are consistent with the literature on antimicrobial coatings, which has reported similar reductions using chitosan-based formulations incorporating plant extracts (Mouhoub et al., 2023b; Casalini & Giacinti Baschetti, 2023). The activity of *O. gratissimum* against *S. aureus* is particularly notable, as this organism is a common cause of skin and soft tissue infections and is frequently found on contaminated surfaces. The high total phenolic content of *O. gratissimum* (142.6 mg GAE/g) is consistent with its strong antibacterial activity, as phenolics are known to disrupt bacterial cell membranes and interfere with cellular processes (Abdoulahi et al., 2023). The MIC values observed (1.25–2.5 mg/mL) are consistent with the literature on Nigerian medicinal plants, which has reported MICs ranging from 0.5 to 10 mg/mL for active extracts.

The durability findings are particularly significant for institutional applications. The retention of antibacterial activity after 20 wiping cycles (2.6 log₁₀ reduction) indicates that the coating would provide effective antibacterial activity between routine cleanings, addressing the gap identified in the literature between periodic cleaning and continuous contamination risk (Mouhoub et al., 2023a). The decline in activity with further wiping and ageing is consistent with the literature, which has reported that antimicrobial coatings have finite durability and require periodic re-application. The excellent adhesion properties (4B rating) indicate that the coating is suitable for application to institutional surfaces, with minimal removal during normal use. The increased hydrophobicity with extract incorporation (contact angle from 68.4° to 78.2°) may also contribute to reduced bacterial adhesion, consistent with the literature on antiadhesion coatings.

The low cytotoxicity of the 5% formulation (82.4% cell viability) is consistent with the literature on plant-based antimicrobials, which are generally considered safe for topical applications at appropriate concentrations. The higher cytotoxicity of the 10% formulation (74.2% viability) indicates a trade-off between efficacy and safety, supporting the selection of the 5% formulation as optimal. The findings of this study are particularly relevant for Nigerian polytechnics, where surface contamination in laboratories and public facilities poses a significant infection risk, and where affordable, sustainable solutions are needed. The use of indigenous plants, particularly *O. gratissimum*, which is widely available in Nigeria and has documented antibacterial properties, makes the coating formulation locally appropriate and cost-effective. The integration of the coating into routine hygiene practices could significantly reduce the transmission of pathogens and antimicrobial-resistant organisms on campus. Overall, the findings confirm that plant-based antimicrobial coatings from indigenous extracts offer a natural, low-cost and durable means of suppressing surface contamination in Nigerian polytechnics, and they provide validated formulations and evidence base for wider adoption.

Conclusion

This study developed and evaluated plant-based antimicrobial surface coatings from indigenous plant extracts for controlling bacterial contamination in laboratories and public facilities in polytechnics in South-West Nigeria. Aqueous and ethanolic extracts of five indigenous plants were screened for antibacterial activity, with *O. gratissimum* and *A. indica* showing the highest activity against *E. coli* and *S. aureus*. The most active extracts were formulated into chitosan-based surface coatings, with the 5% *O. gratissimum* formulation achieving a 3.8 log₁₀ reduction against *S. aureus* and a 3.2 log₁₀ reduction against *E. coli* within 4 hours of contact. Durability testing showed that coated surfaces retained antibacterial activity after 20 wiping cycles (2.6 log₁₀ reduction) and after 30 days of ageing (2.1 log₁₀ reduction). Preliminary cytotoxicity screening indicated no significant toxicity at the active concentrations used (82.4% cell viability). The study provides validated coating formulations and recommendations for institutional surface hygiene. The principal implication is that plant-based antimicrobial coatings from indigenous extracts offer a natural, low-cost and durable means of suppressing surface contamination in Nigerian polytechnics, and that the coating formulation and evidence base developed in this study provide the tools and guidance required to support wider adoption. Future research should extend this work in several directions: evaluating the long-term durability and re-application requirements under real-world conditions; investigating the efficacy of the coatings against a broader range of pathogens, including fungi and viruses; exploring the use of additional indigenous plant species and combinations; and conducting field trials across multiple institutions to evaluate real-world performance.

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Conflict of Interest

The authors declare that there are no competing financial interests or personal relationships that could have influenced the work reported in this study.

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