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Effect of a Mixture Ginger and Lemon Extracts on Bacterial Infection and Healing of Infected Skin Wounds in Local Goats

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Abstract:

This research investigates how 10% ginger (Zingiber officinale) and lemon (Citrus limon) extracts together with their combination affect the treatment of infected skin wounds in 12 local goats. The study created wounds measuring 10-12 cm through surgery and researchers applied daily topical treatments to four different groups including Control and Ginger and Lemon and Mixture groups for seven consecutive days. The VITEK® 2 system performed bacterial species analysis on swab samples which were collected during days 2 to 5. The Control group showed an ongoing rise in total bacterial numbers which reached 40.1 ± 3.5 CFU/ml × 10^4 by Day 5 while developing continuous suppuration and abscess formation. The Mixture group demonstrated the highest bacterial decrease which reached 1.9 ± 0.3 CFU/ml × 10^4 (P0.05) and all E. coli and S. dysgalactiae bacteria disappeared by Day 5. The Mixture group showed the fastest recovery from edema and inflammation signs although the Lemon group experienced initial skin irritation. The research results prove that ginger extract together with lemon extract create a more effective antibacterial solution through their combined effects.

Aims: The research tests how 10% ginger (Zingiber officinale) and lemon (Citrus limon) extracts together with their combined formula help treat skin wounds which carry infections in 12 local goats.

Results: Effect of ginger and lemon mixture extract to reduced the bacterial count.

Conclusions: Lemon extract achieves better bacterial elimination than ginger but it produces first tissue inflammation yet ginger produces a gentler anti-inflammatory effect.

Keyword: Ginger Extract, Lemon Extract, Wound Healing, Local Goats, Antibacterial Activity, Synergistic Effect

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Introduction:

Bacterial skin wound infections in small ruminants produce slow recovery times together with abscess development and blood dissemination of infection (bacteremia).The primary bacteria which cause pyogenic infections in these wounds are Staphylococcus aureus which leads to suppurative inflammation and Pseudomonas aeruginosa which exists as an opportunistic pathogen with strong resistance against standard antibiotic treatments according to (Hanna *et al*., 2024 and Dapgh *et al*., 2019).

Additionally, environmental contaminants like *Escherichia coli* and *Streptococcus dysgalactiae* significantly contribute to wound sepsis and tissue necrosis in goats (Basnet and Kilonzo-Nthenge, 2024). *Staphylococcus aureus* uses virulence factors to avoid host immune detection but *Pseudomonas aeruginosa* develops biofilms which create challenges for applying topical treatments (Wang *et al*., 2020).

Natural plant extracts have emerged as viable alternatives; ginger extract contains bioactive gingerols and shogaols which produce strong anti-inflammatory properties and fight against various types of bacteria. The citric acid and vitamin C content in lemon extract makes it effective at reducing wound pH levels which prevents the development of Gram-negative bacteria including *E. coli* (Bekkouch et al., 2022). The combination of these extracts creates a synergistic effect which produces better antimicrobial results against multi-drug resistant bacterial strains according to current research (Bekkouch et al., 2023; Bekkouch et al., 2025).

The study objectives

To test the ability of ginger and lemon mixture to effect on wound bacteria as an alternative to antibiotics. The research aims to determine how the combination of ingredients speeds up the process of wound healing and tissue regeneration. The research needs to determine which bacterial species show the highest sensitivity to the treatment mixture which will be applied to treated samples.

Materials and Methods:

A. Study Design and Animal Housing

The research took place at the Animal Farm which belongs to the College of Veterinary Medicine at University of Diyala. The research team selected twelve local goats which included male and female animals weighing between 35 and 40 kilograms and aged between 2 and 3 years. The animals lived in a disinfected environment which maintained a consistent level of cleanliness.

The researchers created surgical wounds which measured between 10 and 12 centimeters on the flank area of subjects who received local lidocaine anesthesia at 2% concentration according to (Mala *et al.*, 2021). The researchers allowed the wounds to stay untreated for two days to create

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conditions which resembled actual field environments while the wounds became exposed to soil and animal bedding materials. The wounds remained untreated for two days to replicate natural field environments while the wounds became exposed to soil and animal bedding materials.

Animals were randomly assigned to four equal groups (n=3): a control group (no treatment) and three treatment groups receiving daily topical applications of 10% ginger, 10% lemon, or a 1:1 mixture of both for seven consecutive days.

B. Preparation of Plant Extracts

Fresh ginger rhizomes and lemons were sourced locally and processed to obtain 10% aqueous extracts. The production of ginger extract involved grinding and filtration methods but lemon extract was prepared from fresh juice then both extracts received standardization to 10% concentration through the use of sterile distilled water (Okoruwa and Aidelomon, 2020). The mixture was prepared by combining equal volumes of the 10% ginger and 10% lemon extracts immediately before application to ensure the stability of biologically active compounds (Bekkouch et al., 2023; Saputri et al., 2025).

C. Bacterial Isolation and Identification

Wound swabs were collected aseptically on days 2, 3, 4, and 5 of the experiment. The first stage of isolation took place through the use of selective and differential culture media which included Blood Agar and MacConkey Agar to support the development of pyogenic and enteric pathogens. The VITEK® 2 automated system (bioMérieux) served as the definitive identification tool which delivered precise species identification and complete biochemical profiles for the isolates that included *S. aureus*, *E. coli*, *S. dysgalactiae*, and *P. aeruginosa* (Ali *et al*., 2024; Saha *et al*., 2019).

D.Macroscopic evaluation of wound healing

The study took place on days 7 through 21 to measure wound contraction together with inflammation and scar tissue formation.

Statistical Analysis: The data presentation shows average values with their corresponding standard error of the mean (SEM) from three independent experiments (n=3). The data analysis process involved One-Way ANOVA which Duncan's multiple range test used to perform post-hoc comparisons between each day.

Ethical Approval: The Scientific Ethical Committee of the College of Veterinary Medicine, University of Diyala, Iraq, approved this study (Approval no: Vet Medicine (240); Mar, 2026, R).

Results:

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The clinical results and bacteriological findings showed that each of the four groups followed their own distinct healing patterns. The four bacterial isolates received their identification through routine methods and the VITEK® 2 system which confirmed the combined extract's ability to control Gram-positive pyogenic bacteria and Gram-negative enteric contaminants which speeds up wound healing in goats .

The Control group showed worsening wound pathology through ongoing pus formation and the development of abscesses in specific areas as shown in Figures 2 and 3 and Table 1 which demonstrates bacterial growth from 31.5 ± 2.5 on Day 2 to 40.1 ± 3.5 on Day . The treatment groups demonstrated different levels of bacterial decrease and tissue healing progress.

Figure 1: Surgical section of a linear skin wound on a local goat, showing the initial clean incision prior to treatment.

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Figure 2: Control group show inflammatory reaction with sever swelling & odema with blood clotting & hemorrhage at second day.

Figure 3: Development of abscesses and significant pus formation in an infected wound after fifth Day in control group.

Table 1: The mean of bacterial species from wound swabs of different goat groups during the experimental period.

Group	Day 2	Day 3	Day 4	Day 5
Control	31.5 ± 2.5 ^{A}	35.2 ± 2.8 ^{A}	38.6 ± 3.1 ^{A}	40.1 ± 3.5 ^{A}
Ginger Extract (10%)	30.8 ± 2.4 ^{A}	22.4 ± 1.9 ^{B}	14.1 ± 1.5 ^{B}	7.5 ± 0.9 ^{B}
Lemon Extract (10%)	31.1 ± 2.6 ^{A}	20.9 ± 1.8 ^{B}	12.5 ± 1.3 ^{B}	6.2 ± 0.7 ^{B}
Mixture(Ginger & Lemon)	29.9 ± 2.2 ^{A}	15.3 ± 1.4 ^{c}	7.1 ± 0.8 ^{c}	1.9 ± 0.3 ^{c}

•Different capital letters (A, B, c) in the same column indicate a statistically significant difference ($P<0.05$) between the means of the groups on that specific day.

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The Lemon group exhibited an initial irritant reaction characterized by marked wounded edema and bloody clotting (Figure 4); however, this group was highly effective in lowering the total bacterial count to 6.2 ± 0.7 by Day 5, significantly outperforming the Ginger group in bacterial suppression while show large scar formation with irregular wound edge at 14 Day (Figure 5).

Figure 4: Wound in the Lemon Extract group on fifth day post-treatment, characterized by marked wounded edema and bloody clotting.

Figure 5: Large scar formation with irregular wound edge in the Lemon extract control group after fourteenth day post-treatment, characterized by marked wounded edema and bloody clotting.

The Ginger group presented moderate swelling and a moderate inflammatory reaction (Figure 6) and a gradual resolution of pus by 14 Day (Figure 7), with a total bacterial count of 7.5 ± 0.9. The Mixture group yielded the most superior therapeutic results, where the synergistic effect of the extracts led to a sharp decline in bacterial counts, reaching 1.9 ± 0.3 by Day 5 ($P<0.05$).

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Table 2 further detailed the isolation percentages, showing that the Mixture group achieved total eradication (0%) of *E. coli* and *S. dysgalactiae* by the final days of treatment, while *S. aureus* and *P. aeruginosa* were reduced to minimal levels (4%) .

Figure 6: Wound in the Ginger Extract group on fifth day post-treatment, showing moderate swelling and a moderate inflammatory reaction.

Figure 7: Scar tissue formation with incomplete resolution of wound area in the Ginger Extract control group after fourteenth day post-treatment.

Table 2: Isolation percentage (%) of major bacterial species from goat wounds swabs across the experimental period.

Bacterial Species	Group	Day 2 (%)	Day 3 (%)	Day 4 (%)	Day 5 (%)
Staphylococcus aureus	**Control**	**60**	**55**	**50**	**45**
	Ginger	62	45	25	10

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	Lemon	65	40	20	8
	Mixture	**63**	**25***	**10***	***5>**
Escherichia coli	**Control**	**15**	**15**	**15**	**15**
	Ginger	15	10	5	5>
	Lemon	15	8	5	0
	Mixture	**15**	**5**	**0**	**0**
Streptococcus dysgalact	**Control**	**15**	**15**	**15**	**15**
	Ginger	15	10	8	5
	Lemon	13	10	7	5>
	Mixture	13	8*	*5>	0
Pseudomonas aeruginos	**Control**	**10**	**15**	**20**	**25**
	Ginger	**8**	**10**	**12**	**10**
	Lemon	7	9	8	5
	Mixture	9	8*	5*	*5>

•Different capital letters (A, B, c) in the same column indicate a statistically significant difference ($P<0.05$) between the means of the groups on that specific day.

Macroscopically, the Mixture group showed complete resolution of edema, inflammation, and pus (Figures 8), with the appearance of healthy granulation tissue while show presence pus formation and inflammation after 14 Day (Figure 9).

Figure 8: Wound in the Mixture (Ginger & Lemon) group fifth day post-treatment, exhibiting complete absence of pus formation, inflammation with healthy granulation tissue formation at two weeks

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Figure 9: Mixture (Ginger & Lemon) control group for presence pus formation and inflammation after fourteenth day post-treatment.

Discussion:

The treatment groups show antimicrobial activity because their extracts contain multiple bioactive secondary metabolites which produce this effect. The active components Gingerols and shogaols from ginger achieve their antimicrobial effect through their ability to damage bacterial cell walls while blocking protein production in bacteria which stops their growth. The high citric acid concentration in lemon extract produces an acidic environment which breaks down the enzymes that Gram-negative pathogens use to survive. The multiple biochemical attacks stop bacteria from developing resistance when they try to establish themselves in wound areas. The active elements in these substances help the body move faster from the first stage of inflammation to the second stage of tissue regeneration according to (Bekkouch *et al*., 2022).

The control group showed sustained high levels of *Staphylococcus aureus* and *Pseudomonas aeruginosa* which proves that untreated traumatic wounds lead to dangerous infection risks. The main cause of pyogenic infections comes from *S. aureus* which produces toxins that lead to large areas of tissue destruction and pus formation. The bacteria *P. aeruginosa* establishes biofilms by taking advantage of damaged tissues. The biofilms create physical barriers which defend bacteria against the body's natural immune system and all available topical medications. The pathogens establish an ongoing inflammatory condition which stops the body from producing normal granulation tissue when left untreated. Medical staff must apply topical treatment during the initial stages of infection because this approach stops localized infections from turning into systemic infections (Hanna *et al*., 2024).

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The information from Table 1 shows that lemon extract produces a strong antibacterial effect which performed better than ginger in bacterial reduction even though it led to initial skin inflammation because of its acidic nature (Saputri *et al*., 2025).

The acidic conditions create a hostile environment which causes Gram-negative bacteria including *E. coli* to die off rapidly (Ridler *et al*., 2019) .

The ginger group showed a clear therapeutic benefit because they controlled the wound environment through their distinct plant-based chemical composition. Ginger produces antibacterial effects which directly fight bacteria but its capability to reduce pro-inflammatory cytokines leads to decreased wound site swelling and tissue pressure. The anti-inflammatory effect serves as a vital component which protects microvascular structures to sustain proper oxygen and nutrient delivery for tissue regeneration. The data shows that bacterial levels dropped continuously in this group which indicates their antimicrobial treatment remains effective for maintaining tissue health over long periods. The healing power of ginger extends past basic infection prevention because it creates an optimal environment which supports tissue regeneration according to Kilimanjaro S.J. 2021 and Wang *et al*. 2020.

The Mixture group achieved the best results because their CFU/ml count dropped to 1.9 ± 0.3 which shows a strong combined effect between lemon acidity and ginger anti-inflammatory action (Bekkouch et al., 2023; Bekkouch et al., 2025). Our research findings about antimicrobial effectiveness against goat wound isolates match the research results published by Kadhim in 2023.

The combined effect of these elements removed the lemon's irritating impact while it sped up the complete elimination of *E. coli* and *S. dysgalactiae* as described in Table 2 (Jia et al., 2025).

The human wound healing process advances through three distinct phases which include the inflammatory stage and the proliferative stage and the remodeling stage. The body enters the inflammatory phase by displaying red skin along with swollen tissue and fluid discharge at the wound site where immune cells begin their response. The wound displays bright red moist granulation tissue during the proliferative phase which indicates successful blood vessel formation and collagen synthesis. The mixture group showed visual pus clearance together with healthy granulation tissue development which proved the combination effectively combats infections while supporting tissue healing. The combined extract functions as an effective treatment method which resolves complicated veterinary wound infections based on the current research results. The wound shows progress through epithelialization and tissue healing because it contracts while forming a scab which becomes dry and stable. The process of visual change observation helps clinicians evaluate the success of their treatment methods when it comes to skin healing (Mala *et al*., 2021).

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Conclusions:

The 10% ginger and lemon mixture serves as the best solution which produces a total bacterial count of 1.9 ± 0.3 and eliminates enteric species by the fifth day. Lemon extract kills bacteria more effectively than ginger does but it first causes tissue irritation although ginger produces a less intense anti-inflammatory effect. The combined power of both extracts speeds up wound healing while creating a stronger antibacterial defense than using each extract separately.

Recommendations:

The combination of ginger (Zingiber officinale) and lemon extracts serves as an effective natural alternative therapy for healing goat wound infections because they fight microbes and neutralize free radicals.

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Conflict of Interest:

The authors declare no conflict of interest

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Authors Contributions:

The author was responsible for the experimental work, data analysis and preparation of the manuscript.

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