

Antibacterial Activity of Ethanolic Extract of Torch Ginger (*Etlingera elatior*) Towards *Enterococcus faecalis*: A Preliminary Research to the Alternative of Root Canal Irrigant of Primary Teeth

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ABSTRACT

Enterococcus faecalis is a notable pathogen found in the root canals of primary teeth with endodontic infections, often resistant to conventional root canal irrigation solutions, leading to treatment failure. Torch ginger or kecombrang (*Etlingera elatior*), a spice plant, is reported to contain bioactive compounds with antibacterial properties. This study investigates the antibacterial efficacy of ethanolic extract of torch ginger against *Enterococcus faecalis*, evaluating its potential as an alternative irrigant based on minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), and effective concentration. Samples included *Enterococcus faecalis* ATCC[®] 29212[™] and 70% ethanol extract of torch ginger, tested in eight concentrations (80%, 75%, 65%, 50%, 25%, 12.5%, 6.25%, and 3.125%) obtained through maceration, alongside two control groups (NaOCl and saline). The Kirby-Bauer disc diffusion method was employed to determine MIC, while the streaking method from MIC testing identified MBC. Data analysis for MIC and MBC values was conducted using the One-Way ANOVA parametric test ($p < 0.05$). Torch ginger extract demonstrated antibacterial activity against *Enterococcus faecalis*, with inhibition observed at a minimum concentration of 3.125% with average inhibition zone diameter of 9.63 ± 0.25 mm and reaching up to 80% concentration with average inhibition zone diameter of 15.03 ± 0.21 mm. The MIC was established at 3.125%, and the MBC among the tested concentrations was 80%. The study concludes that the ethanolic extract of torch ginger shows significant antibacterial activity against *Enterococcus faecalis*. An 80% concentration is identified as the most effective for inhibiting and killing the pathogen, suggesting its potential as an alternative root canal irrigant of primary teeth.

Keywords: *Enterococcus faecalis*, ethanolic extract of torch ginger (*Etlingera elatior*), minimum bactericidal concentration (MBC), minimum inhibitory concentration (MIC).

1. INTRODUCTION

The oral cavity serves as a critical interface between the internal and external environments of the human body, functioning as a gateway for infectious microorganisms [1]. It is the second most microbially diverse region of the body after the intestines, harboring over 700 species of microbes, including bacteria [2]. Among these, *Enterococcus* is a significant infectious bacterium in the oral cavity.

Enterococcus faecalis (*E. faecalis*) is a facultative Gram-positive bacterium capable of surviving in both aerobic and anaerobic conditions [3]. As a pathogenic agent in the oral cavity, *E. faecalis* is implicated in various oral infections such as marginal periodontitis, oral mucosal lesions, peri-implantitis, caries, and endodontic infections [1], [4].

Enterococcus faecalis (*E. faecalis*) is one of the prevalent bacteria in the root canals of primary teeth affected by

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endodontic infections, such as pulp necrosis accompanied by fistulas [4]–[6]. Prevalence studies indicate that *E. faecalis* dominates among the microorganisms causing endodontic infections, accounting for 40% to 79.5% of cases [7]–[9]. *E. faecalis* is notable for its ability to survive in adverse and nutrient-poor conditions [7], [10]. Additionally, it can form biofilms within the root canal, providing protection against the host's immune defence and disinfectant agents [7], [10], [11]. The biofilm formation enhances *E. faecalis* survival in unfavorable conditions [10], [11]. This increased pathogenicity and biofilm production is attributed to the virulence factors possessed by the bacteria [7], [10].

The management of endodontic infections involves a procedure known as root canal treatment (RCT), which aims to eradicate infections by removing the infected pulp from the root canal system [8], [12]. The primary goals of RCT are to eliminate and inhibit the growth of infectious agents within the root canal system, and to alleviate inflammation and pain [12]. RCT involves several stages, including cleaning, shaping, and obturation of the root canal. Cleaning the root canal is typically achieved through the use of irrigating solutions [8]. Sodium hypochlorite (NaOCl) is considered the gold standard for root canal irrigation due to its effectiveness in eradicating *E. faecalis* [13], [14]. However, NaOCl has been reported to be toxic, and its combination with chlorhexidine can produce parachloroaniline, a carcinogenic compound that poses risks to peri-radicular tissue [15], [16]. Furthermore, the wide apical foramen of primary teeth can lead to NaOCl extrusion, irritating periapical tissues and potentially affecting the development of permanent tooth germs [17]. These concerns underscore the need for research into the antibacterial properties of natural materials, such as herbal plants, which could serve as safer alternatives to conventional irrigation solutions for root canal treatment in primary teeth.

Herbal plants have long been utilized by the Indonesian people for addressing various health problems due to their bioactive compounds, which are believed to possess therapeutic properties [18]. *Etilingera elatior* (Jack) R.M. Sm or torch ginger, commonly known as kecombrang, is a native Indonesian flora that thrives throughout the archipelago [19]–[21]. Torch ginger is reputed to offer numerous benefits, including enhancing the flavor of traditional dishes such as arsik carp, preserving fish meat, eliminating body odor, and serving as an ingredient in soap and shampoo. Additionally, it is used for treating ear infections and cleaning wounds [22], [23]. These benefits are attributed to the presence of bioactive compounds in kecombrang, which exhibit antimicrobial properties [21].

Phytochemical screening of torch ginger reveals the presence of bioactive compounds such as flavonoids, alkaloids, polyphenols, steroids, saponins, and essential oils [23], [24]. Research on torch ginger extract has particularly highlighted flavonoids as the primary bioactive compounds with notable antibacterial properties [21], [25], [26]. Flavonoids, belonging to the phenolic group, exhibit antibacterial activity through mechanisms that include disrupting the peptidoglycan cross-links in bacterial cell walls and inhibiting cellular metabolism [21], [26], [27]. The

cell wall structure of Gram-negative bacteria is composed of complex lipids and is less polar compared to Gram-positive bacteria, which have cell walls primarily made of polar teichoic acid and peptidoglycan [25], [27]. The polar nature of these bioactive compounds allows them to penetrate the cell walls of Gram-positive bacteria more easily, leading to cell wall damage and inhibition of bacterial activity [28].

Building upon the known antibacterial properties of torch ginger and its bioactive compounds, this study aims to achieve two primary objectives. Firstly, it seeks to identify the specific antibacterial bioactive compounds present in the ethanolic extract of torch ginger. Secondly, it evaluates the antibacterial activity of this extract against *Enterococcus faecalis* by determining minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC), as well as identifying the effective concentration. These findings will help assess the feasibility of using torch ginger extract as an alternative root canal irrigant for primary teeth.

2. MATERIALS AND METHODS

This study employs an experimental research methodology, specifically utilizing a post-test only with a controlled group design. Ethical clearance approval was granted in 2023 by the Health Research Ethics Commission under license number 1145.

2.1. Sample Size

The sample size for this study was determined using the Federer formula, $(t-1)(r-1) \geq 15$, where “t” represents the number of treatment groups and “r” represents the number of replications. In this study, there were 10 treatment groups, including 8 test concentration groups of torch ginger ethanolic extract (80%, 75%, 65%, 50%, 25%, 12.5%, 6.25%, and 3.125%) and 2 control groups (NaOCl and saline). Each concentration and control group was replicated three times. Consequently, the total sample size for the study was 30.

2.2. Preparation of Torch Ginger *Simplicia*

The preparation of torch ginger *simplicia* involves several systematic stages: collection, sorting, cleaning, weighing, and drying. The torch gingers were sourced from Sukamandi Village, Merek District, Karo Regency, with a total weight of 5 kg. The kecombrang flowers or torch gingers were identified at the USU Medanense Herbarium (MEDA) laboratory of plant systematics (No.1469/MEDA/2023). The torch gingers were washed under running water and allowed to drain for approximately 15 minutes. Subsequently, the orch gingers were trimmed at the base of the bud and sliced into smaller pieces. These slices were dried in a *simplicia* dryer cabinet at 40 °C until they became brittle. The dried torch gingers were then ground into a fine powder using a blender for approximately 3 minutes. The resulting torch ginger powder was weighed and stored in tightly sealed containers to maintain its quality.

2.3. Extraction Procedure of Torch Ginger Bioactive Compounds

The extraction of torch gingers was performed using the cascade maceration method. The extraction process began by preparing a glass jar to mix and soak 208 g of dried torch ginger powder with 2000 ml of 70% ethanol. The mixture was stirred continuously for the first 6 hours and then allowed to stand for 24 hours with occasional stirring. After the initial maceration period, the mixture was filtered using filter paper to obtain the first macerate. The extraction process was repeated using an additional 1000 ml of 70% ethanol for another 3 × 24 hours to obtain the second macerate. The first and second macerates were then combined and subjected to evaporation using a rotary evaporator at 40 °C to remove the solvent, resulting in a viscous extract.

2.4. Preparation of *Enterococcus faecalis* Suspension

The test bacteria were inoculated using a sterile inoculating loop, which was then dissolved in 10 ml of 0.9% NaCl solution in a test tube. The suspension was homogenized using a vortex mixer until the turbidity matched that of a 0.5 McFarland standard, indicating a bacterial concentration of 10⁸ CFU/ml. Subsequently, a dilution was performed by mixing 0.1 ml of the bacterial suspension with 9.9 ml of Mueller-Hinton Broth (MHB) in a test tube. This mixture was homogenized again with a vortex mixer to achieve a bacterial inoculum with a turbidity of 10⁶ CFU/ml.

2.5. Antibacterial Activity Test Procedure and Determination of MIC

Antibacterial activity was evaluated using the Kirby-Bauer disc diffusion method. Sterile paper discs were immersed in various concentrations of torch ginger ethanol extract (*Etligeria elatior*) at 3.125%, 6.25%, 12.5%, 25%, 50%, 65%, 75%, and 80% for 10 minutes. As controls, paper discs were also immersed in sodium hypochlorite (2.5% NaOCl) and saline solution (0.9% NaCl) to serve as positive and negative controls, respectively. After absorption of the extracts and control solutions, the paper discs were placed on Mueller-Hinton Agar (MHA) plates that had been uniformly inoculated with *Enterococcus faecalis*. The plates were incubated at a constant temperature of 37°C for 24 hours. Following incubation, observations were made to determine the effective concentration for inhibiting the growth of *E. faecalis*. The diameter of the inhibition zones was measured using a caliper. The minimum inhibitory concentration (MIC) was identified as the lowest concentration of the extract that produced a measurable inhibition zone.

2.6. Antibacterial Activity Test Procedure and Determination of MBC

The minimum bactericidal concentration (MBC) was determined by colony count analysis. A total of 30 test tubes, each containing 2 ml of Mueller-Hinton Broth (MHB), were prepared. Sterile cotton swabs were used to collect samples from the clear zones formed during the minimum inhibitory concentration (MIC) tests. Each swab

was dipped into the respective test tube and left for 10 minutes. *E. faecalis* from the swabs were then inoculated onto Plate Count Agar (PCA) media. The plates were incubated at 37 °C for 24 hours. Post-incubation, the plates were observed for bacterial colony growth to identify the lowest concentration at which no bacterial growth occurred. The final step in determining the MBC involved counting the number of colonies using a colony counter and comparing the results between the control and treatment groups. The MBC value was identified as the concentration capable of reducing the number of bacterial colonies by 98.0%–99.9% compared to the initial bacterial count (negative control). The percentage reduction in colony numbers was calculated using the formula provided by Nasri *et al.* [29].

$$\text{Percent Reduction} = \frac{(B - A)}{A} \times 100\%$$

Information:

A = Number of *E. faecalis* bacterial colonies at extract concentration.

B = Number of *E. faecalis* bacterial colonies (negative control).

2.7. Phytochemical Screening

2.7.1. Flavonoids

To detect the presence of flavonoids in torch ginger simplicia, 1 g of the simplicia was added to 10 ml of hot water and boiled for five minutes. The mixture was then filtered to obtain a clear filtrate. Subsequently, 5 ml of the filtrate was combined with 0.1 g of magnesium powder, 1 ml of concentrated hydrochloric acid (HCl), and 2 ml of ethanol. The solution was shaken vigorously and allowed to separate. A color change in the solution to red, orange, or yellow indicated a positive result for flavonoids in the torch ginger extract.

2.7.2. Alkaloids

One gram of torch ginger simplicia was dissolved in 10 ml of 2N HCl to prepare three solution samples for different reagents. Each solution was then tested with Mayer's, Bouchardat's, and Dragendorff's reagents. A positive result for alkaloids was indicated by the formation of a white precipitate upon the addition of Mayer's reagent to the test solution. Bouchardat's reagent caused a brown color change, while Dragendorff's reagent resulted in a red precipitate formation in the test solution.

2.7.3. Saponins

One gram of torch ginger simplicia was added to 10 ml of hot water and vigorously shaken in a test tube for 10 seconds to produce foam. A few drops of 2N HCl were then added, and the tube was shaken again until foam appeared. The stability of the foam height was observed for 10 minutes. The presence of stable foam indicated a positive result for saponins in the torch ginger extract.

2.7.4. Tannins

One gram of torch ginger simplicia was brewed with 10 ml of warm water until the color of the brew faded. A few drops of 1% FeCl₃ were added to the solution and observed for any color change. The presence of tannins in

TABLE I: PHYTOCHEMICAL SCREENING RESULTS OF ETHANOLIC EXTRACT OF TORCH GINGER

No.	Secondary metabolites	Reagents	Result*
1	Alkaloids	Dragendroff Bouchardat Meyer	(-)
2	Flavonoids	Mg powder + amyl alcohol + HCl	(+)
3	Glycosides	Molish + H ₂ SO ₄	(+)
4	Saponins	Hot water/shaken	(+)
5	Tannins	FeCl ₃	(+)
6	Triterpenoids	Lieberman-Bouchard	(+)

Note: * Information: (-) = The extract does not contain such secondary metabolites.

(+) = The extract contains the secondary metabolite compounds.

the torch ginger extract was confirmed by a color change in the solution to blue-black or blue-green.

2.7.5. Steroid and Triterpenoids

One gram of torch ginger simplicia was macerated with 20 ml of ether for two hours, and the filtrate was then evaporated. To the residue, 10 drops of anhydrous acetic acid and 3 drops of concentrated H₂SO₄ were added, and the mixture was observed for any color changes. A change in color to purple or red indicated the presence of triterpenoids in the torch ginger extract, while a green or blue color change indicated the presence of steroids.

3. RESULT

Phytochemical screening of the ethanolic extract of torch ginger was conducted to evaluate its antibacterial activity against *E. faecalis*. The study was performed at the Phytochemistry Laboratory, Faculty of Pharmacy, University of Sumatera Utara. The phytochemical analysis identified several secondary metabolite compounds, as summarized in Table I:

The study results demonstrated that the extract of torch ginger exhibited significant antibacterial activity against *E. faecalis*. This activity was evidenced by the formation of a clear inhibition zone around the paper disc, as shown in Fig. 1.

Based on the observation of the inhibition zones (Table II), the study determined that the minimum inhibitory concentration (MIC) of torch ginger extract against *E. faecalis* was 3.125%. This concentration was established as the MIC because it is the lowest concentration at which the extract effectively inhibited the growth of *E. faecalis*.

The minimum bactericidal concentration (MBC) of torch ginger extract against *E. faecalis* was determined using the streaking method on the clear zones formed at each concentration that exhibited the MIC. The MBC value was identified as the lowest concentration of the extract capable of reducing 98.0%–99.9% of the *E. faecalis* colonies, compared to the negative control as shown in Fig. 2.

The One-Way ANOVA test results of the antibacterial activity of torch ginger extract against *E. faecalis* indicated a significant difference across various concentrations, with a p-value of 0.000 ($p < 0.05$) (Table III). This demonstrates

a statistically significant effect of the torch ginger extract on inhibiting and killing *E. faecalis*.

The Post Hoc Test results revealed a p-value of less than 0.05, indicating a statistically significant difference in the inhibition zones and colony counts at each concentration of torch ginger extract against *E. faecalis*. These findings confirm the antibacterial activity of the torch ginger extract. Specifically, the LSD Post Hoc Test demonstrated a significant difference between the positive control (NaOCl) and both the ethanolic extract of torch ginger and the negative control (saline), with a p-value of 0.000 ($p < 0.05$). This suggests that while NaOCl remains the more effective root canal irrigation material for inhibiting and killing *E. faecalis*, the ethanolic extract of torch ginger exhibits superior antibacterial activity compared to saline.

This study supports the alternative hypothesis that torch ginger extract exhibits antibacterial activity against *E. faecalis*. This conclusion is based on the observed Minimum Inhibitory Concentration (MIC), Minimum Bactericidal Concentration (MBC), and effective concentrations.

4. DISCUSSION

This in vitro laboratory experimental research investigates the antibacterial activity of torch ginger extract (*Etilingera elatior* (Jack) R.M.Sm., or *E. elatior*) against *E. faecalis*. Prevalence studies have reported that microorganisms, particularly *E. faecalis*, are a leading cause of endodontic infections, with an incidence rate ranging from 40% to 79.5% [7]–[9]. The research sample consisted of *E. faecalis*, a Gram-positive bacterium commonly found in the root canals of primary teeth with endodontic infections, such as pulp necrosis [4]–[6]. The bacterial strain used in this study was *Enterococcus faecalis* ATCC® 29212™, obtained from the American Type Culture Collection.

The torch ginger extract concentrations used in this study were 80%, 75%, 65%, 50%, 25%, 12.5%, 6.25%, and 3.125%. These concentrations were selected to determine the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extract's antibacterial activity. Phytochemical screening revealed the presence of bioactive compounds with antibacterial properties (Table I). Previous studies have reported that torch ginger extract exhibits sensitivity in inhibiting the

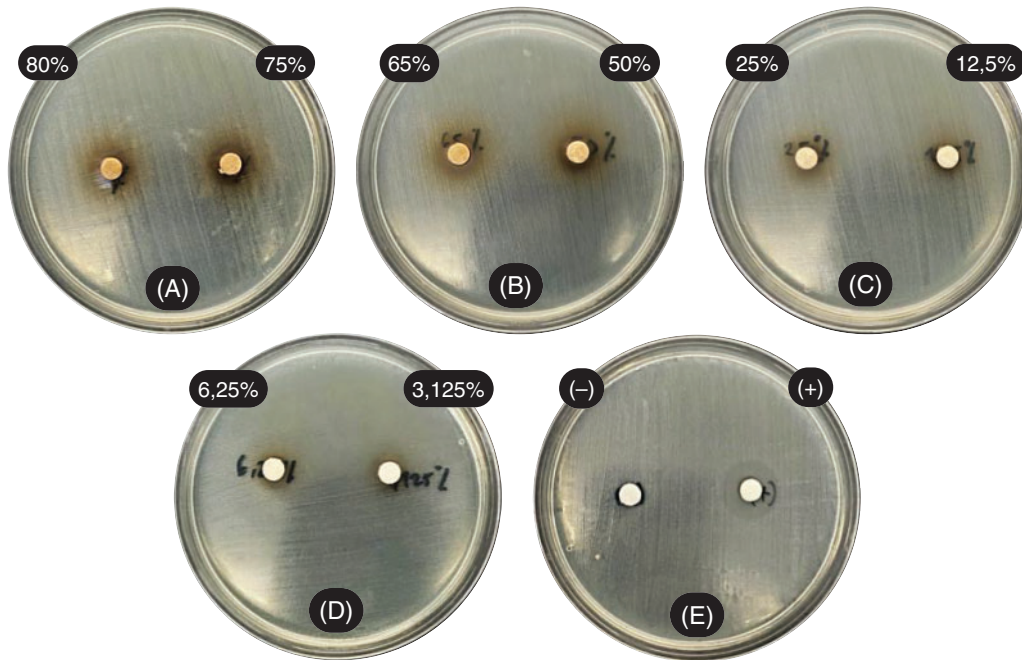


Fig. 1. Inhibition zones formed at various concentrations of torch ginger extract: (A) 80% and 75%, (B) 65% and 50%, (C) 25% and 12.5%, (D) 6.25% and 3.125%, (E) Positive control and negative control.

TABLE II: AVERAGE DIAMETER OF THE INHIBITION ZONES PRODUCED BY THE ETHANOLIC EXTRACT OF TORCH GINGER AGAINST *E. faecalis*

No.	Extract concentration (%)	Diameter of clear zone (mm)			Average inhibitory zone ($\bar{X} \pm SD$) (mm)
		Repetition			
		1	2	3	
1	80%	14.8	15.2	15.1	15.03 \pm 0.21
2	75%	14.5	14.4	14.7	14.50 \pm 0.15
3	65%	13.6	13.4	13.7	13.57 \pm 0.15
4	50%	12.3	12.7	12.5	12.50 \pm 0.20
5	25%	11.2	11.3	11.1	11.20 \pm 0.14
6	12.5%	11	10.5	10.8	10.77 \pm 0.25
7	6.25%	10.3	10.1	10.4	10.27 \pm 0.15
8	3.125%	9.6	9.4	9.9	9.63 \pm 0.25
9	(+): NaOCl	17	17.1	16.8	16.97 \pm 0.15
10	(-): Saline	0	0	0	0

Note: * Information: 0 = It has not been able to inhibit the growth of bacteria.

TABLE III: ONE-WAY ANOVA RESULTS FOR THE ANTIBACTERIAL ACTIVITY OF TORCH GINGER EXTRACT IN INHIBITING THE GROWTH AND KILLING OF *E. faecalis*

No.	Extract concentration	n	p-value
1	80%	3	0.000*
2	75%		
3	65%		
4	50%		
5	25%		
6	12.5%		
7	6.25%		
8	3.125%		
9	(+): NaOCl		
10	(-): Saline		

Note: * Information: p-value < 0.05 = significant.

growth of Gram-positive bacteria, including *Staphylococcus aureus*, *Propionibacterium acnes*, and *Staphylococcus epidermidis* [25], [27].

Antibacterial research conducted at the Microbiology Laboratory, Faculty of Medicine, University of Sumatera Utara, demonstrates that torch ginger extract exhibits significant antibacterial activity against *E. faecalis* (Tables II and IV). The antibacterial effect was assessed by observing the inhibition zones, indicated by clear zones formed around the extract application sites (Fig. 1). The study observed that an increase in extract concentration corresponded to a wider inhibition zone diameter. These findings suggest that higher concentrations of the extract enhance the diffusion rate, thereby increasing the antibacterial effect and resulting in larger inhibition zones [30].

The research on the antibacterial activity of torch ginger extract against *E. faecalis* aligns with the findings of Syafriana et al. [26], who investigated the effects of torch ginger extract at concentrations of 10%, 20%, 40%, and 80% against *Staphylococcus epidermidis* using a 70% ethanol solvent. Their study reported that the 80% concentration yielded the highest average inhibition zone of 14.41 ± 0.02 mm, while the 10% concentration resulted in the smallest

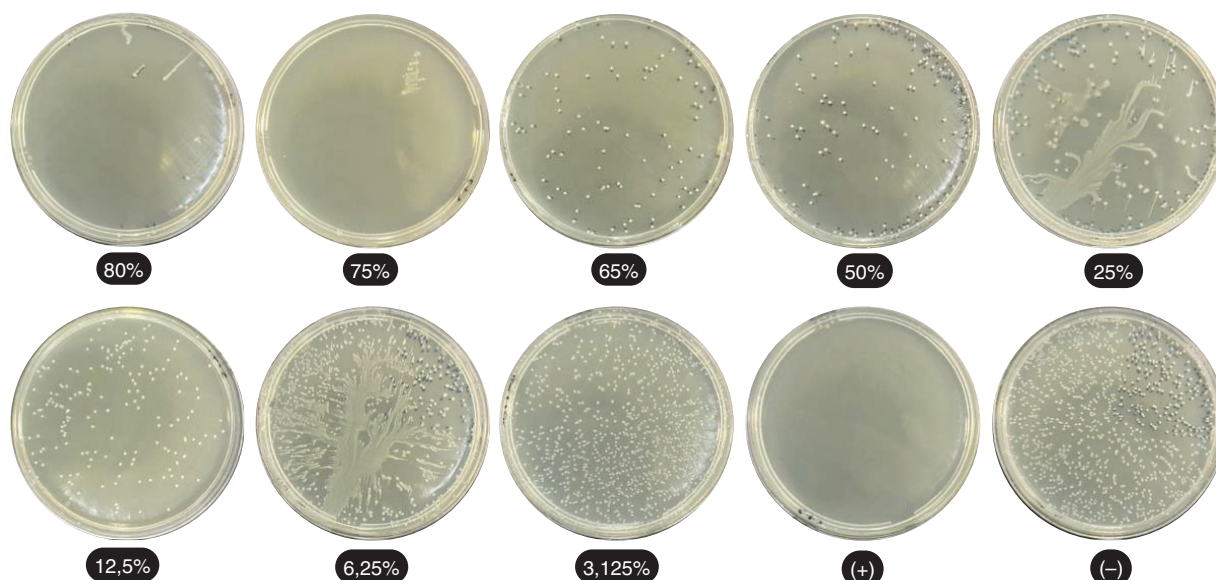


Fig. 2. Colonies of *E. faecalis* formed from streaking the inhibition zones at various concentrations: 80%, 75%, 65%, 50%, 25%, 12.5%, 6.25%, 3.125% and control groups.

TABLE IV: RESULTS OF THE CALCULATION OF THE BACTERICIDAL ACTIVITY OF THE ETHANOL EXTRACT OF TORCH GINGER ON THE NUMBER OF *E. faecalis* COLONIES

No.	Extract concentration	Number of colonies (CFU/ml) (X ± SD)	Difference (B-A)	Percent reduction
1	80%	23.33 ± 1.53	1156.67	98.02%
2	75%	43.67 ± 1.53	1136.33	96.30%
3	65%	95.67 ± 2.52	1084.33	91.89%
4	50%	169.67 ± 3.06	1010.33	85.62%
5	25%	311.33 ± 2.08	868.67	73.62%
6	12.5%	419.33 ± 2.52	760.67	64.46%
7	6.25%	523.67 ± 3.06	656.33	55.62%
8	3.125%	616.33 ± 2.08	563.67	47.77%
9	(+): NaOCl	0.00 ± 0.00	1180.00	100.00%
10	(-): Saline	1180.00 ± 4.00	0	0%

average inhibition zone of 10.62 ± 0.06 mm. In the present study, torch ginger extract against *E. faecalis* produced an inhibition zone of 9.63 ± 0.25 mm at the lowest concentration of 3.125% with a 70% ethanol solvent. Variations in bacterial strains, extract solvents, and growth conditions of the sample plants can influence the inhibitory effects of an extract [28], [31].

Research on torch ginger extract with various bacteria and solvents has demonstrated significant antibacterial activity. Delta *et al.* [32], investigated the methanol extract of torch ginger at concentrations of 40%, 60%, and 80% against *Staphylococcus aureus*, reporting that a 40% concentration formed an inhibition zone of 17.6 mm. Similarly, Anggraini *et al.* [33], studied the ethanol extract of torch ginger at concentrations of 10%, 20%, 30%, 40%, and 50% against *Klebsiella pneumoniae*, finding that the lowest concentration of 10% formed an inhibition zone of 8.7 mm. These studies collectively indicate that torch ginger extract possesses antibacterial properties capable of inhibiting various bacterial strains, regardless of the solvent used.

The antibacterial activity of torch ginger extract is attributed to its bioactive compounds, which have inherent

antibacterial properties. Qualitative phytochemical screening conducted at the Phytochemistry Laboratory of the Faculty of Pharmacy, University of Sumatera Utara, revealed that the ethanolic extract of torch ginger contains several bioactive compounds, including flavonoids (as the main compound), tannins, saponins, glycosides, and triterpenoids (Table I). Flavonoids, tannins, and saponins are particularly abundant in torch ginger [28]. These bioactive compounds exhibit different antibacterial mechanisms. Flavonoids disrupt bacterial cell walls by breaking peptidoglycan cross-links, leading to bacterial lysis. Tannins inhibit bacterial growth by interfering with the production of reverse transcriptase enzymes and weakening bacterial adhesins, which releases bacteria attached to biofilms on the root canal wall. Saponins, being part of the detergent class, reduce cell surface tension and disrupt the permeability and stability of bacterial cell membranes, causing cytoplasmic leakage and subsequent bacterial cell death [28].

Gram-positive bacteria possess a relatively simple cell wall structure, primarily composed of teichoic acid and peptidoglycan, both of which exhibit polar characteristics. In contrast, Gram-negative bacteria have a more complex and less polar cell wall composition [25], [27]. Torch ginger

extract is rich in bioactive compounds such as flavonoids, tannins, and saponins, which are polar in nature. These polar bioactive compounds can readily penetrate the cell wall of Gram-positive bacteria, leading to cell wall damage and subsequent inhibition of bacterial activity [28]. This mechanism underlies the observed potent antibacterial properties of torch ginger extract, making it particularly effective against Gram-positive bacteria such as *E. faecalis*.

This study demonstrates the antibacterial activity of torch ginger extract against *E. faecalis*, as evidenced by the formation of inhibition zones at various test concentrations (Fig. 1). According to the classification by Davis and Stout [34], antibacterial activity can be categorized based on the diameter of the inhibition zone: weak (<5 mm), moderate (5–10 mm), strong (10–20 mm), and very strong (>20 mm) [35]. In this study, a concentration of 3.125% of torch ginger extract exhibited moderate antibacterial activity, with an inhibition zone diameter between 5 and 10 mm, identifying it as the minimum inhibitory concentration (MIC). Concentrations ranging from 6.25% to 80% displayed strong antibacterial activity, with inhibition zone diameters falling within the 10–20 mm range.

The Ministry of Health of the Republic of Indonesia (1998) established a reference standard for assessing the microbial effectiveness of antimicrobial agents derived from medicinal plants. According to this standard, an antimicrobial is considered effective if the inhibition zone measures between 12 and 24 mm [28]. Following this guideline, our study found that torch ginger extract at concentrations of 50%, 65%, 75%, and 80% was effective in inhibiting *E. faecalis*. Notably, only the 80% concentration demonstrated bactericidal activity against *E. faecalis*. According to Sovira et al. [36], to qualify as an alternative root canal irrigation material, a substance must not only inhibit but also kill the test bacteria, such as *E. faecalis*. In this study, the 80% concentration of torch ginger extract exhibited both effective inhibitory and bactericidal properties, indicating its potential as an alternative root canal irrigation material.

The potential of torch ginger extract as an alternative root canal irrigation material involves several considerations, particularly its viscosity and rheological properties [37]. The concentration of torch ginger extract significantly influences its viscosity and flowability; higher concentrations result in increased viscosity, thereby reducing flowability. Optimal flowability is crucial for root canal irrigation materials to ensure thorough disinfection of the root canal walls and penetration into the dentin and tubules [37]. Therefore, further research is warranted to evaluate the preparation and efficacy of torch ginger extract solutions for use as root canal irrigation materials.

Another consideration for employing torch ginger extract as an alternative root canal irrigation material pertains to the complexity of its manufacturing process and the associated costs. Comparatively, sodium hypochlorite (NaOCl), the current gold standard for root canal irrigation, is more economical. However, torch ginger extract presents distinct advantages: it is biocompatible, non-toxic, and safe, with minimal adverse effects attributable to its natural origin [38]. Conversely, NaOCl exhibits cytotoxicity and irritant properties when in contact with periapical

tissues, possesses a bitter taste and unpleasant odor, and can compromise the mechanical properties of dentin by reducing its strength and modulus of elasticity [38].

Research by Gupta et al. [39] demonstrated that an ethanolic extract of cinnamon (*Cinnamomum zeylanicum*), rich in phenylpropanoid compounds, effectively eradicated *E. faecalis* at a concentration of 10%, indicating its potential as an alternative root canal irrigation material. Similarly, a study by Tekin et al. [40] reported that noni juice (*Morinda citrifolia*), containing antibacterial alkaloid compounds, inhibited *E. faecalis* growth at a 6% concentration. Additionally, the combination of noni juice with sodium hypochlorite (NaOCl) and ethylenediaminetetraacetic acid (EDTA) proved effective as a final irrigation solution. Based on these findings, further research should explore the potential synergistic effects of combining ethanolic extracts of torch ginger with other natural or conventional irrigation materials to enhance the efficacy of root canal treatments using natural substances.

The antibacterial activity of torch ginger extract or kecombrang (*Etilingera elatior*) is notably potent. This extract demonstrates significant potential as an alternative root canal irrigation material due to its ability to inhibit and eradicate *E. faecalis*, a predominant bacterium in root canal infections, at an effective concentration of 80%.

5. CONCLUSIONS

The minimum inhibitory concentration (MIC) of torch ginger extract was determined to be 3.125%, while the minimum bactericidal concentration (MBC) was found to be 80%. The extract, at a concentration of 80%, demonstrates effective antimicrobial properties, indicating its potential as an alternative root canal irrigation agent. Further research is warranted to perform a comprehensive quantitative phytochemical analysis. This study is limited by its focus on a single bacterial species; hence, future research should include a broader spectrum of bacteria associated with endodontic infections. Advanced studies, both ex-vivo and in-vivo, are essential to validate these findings. Additionally, research on the rheological properties and viscosity of the torch ginger extract is recommended. Combining the ethanolic extract of torch ginger with other natural substances or conventional irrigation solutions could also be explored to enhance its efficacy.

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