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Research Article

Antidiarrheal Potential and Phytochemical Profile of Different Solvent Extract of Jambu Wer (*Elaeocarpus longifolius*)

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ABSTRACT

The ethnopharmacological significance of Elaeocarpus longifolius (Jambu Wer), an indigenous medicinal plant of the Tengger Tribe, remains underexplored. This study evaluates the antibacterial and phytochemical properties of E. longifolius fruit extracts using ethanol, n-hexane, ethyl acetate, and chloroform as solvents. Antibacterial activity was assessed against Escherichia coli and Shigella dysenteriae, pathogens commonly associated with severe diarrhea, using the agar disk-diffusion method. Phytochemical screening was conducted using reagent-based tests and thin-layer chromatography (TLC). The ethanol extract exhibited the highest antibacterial activity, with inhibition zones exceeding 20 mm against both bacterial species. Phytochemical analysis revealed the presence of alkaloids, flavonoids, and tannins (compounds known for their pharmacological properties). These findings highlight the potential of E. longifolius ethanol extract as a promising natural therapeutic candidate for the development of Fitofarmaka targeting diarrheal diseases.

Keywords: *Antibacterial activity; Diarrheal diseases; Elaeocarpus longifolius; Phytochemicals; Solvent variations.*

Introduction

Diarrhea remains a significant public health issue in Indonesia, with the potential to escalate into extraordinary events and contributing to substantial morbidity and mortality, particularly among toddlers [1]. According to the Indonesian Ministry of Health, diarrhea prevalence in Indonesia reached 9.8%, with mortality rates of 14.5% and 4.55% among toddlers aged 12–59 months [2]. This aligns with global data from WHO and UNICEF, which estimate approximately 2 billion diarrhea cases annually, resulting in 1.9 million toddler deaths worldwide [3]. The 2018 Basic Health Research and the 2020 Indonesian Nutritional Status Survey further emphasize the severity of this condition, identifying diarrhea as one of the most prevalent digestive tract infections globally [4].

Etiologically, diarrhea is categorized into non-specific and specific types [5], [6]. Non-specific diarrhea arises

from food sensitivities, such as fructose or lactose intolerance, often triggered by the excessive consumption of sour, spicy, or coconut milk-based foods [7], [8]. Specific diarrhea, in contrast, results from bacterial, viral, or parasitic infections, with *Escherichia coli* and *Shigella dysenteriae* being common bacterial culprits [9─12]. These pathogens produce toxins that irritate the intestinal mucosa, leading to symptoms such as dehydration, which is particularly fatal in infants and young children [13].

Ethnomedicinal traditions in Indonesia frequently utilize plant-based remedies to address diarrhea[14], [15], [16]. Among these, the unripe fruits of *Elaeocarpus longifolius* (locally known as Jambu Wer) are widely recognized for their therapeutic potential. This practice is particularly prominent within the Tengger indigenous community, where the fruit is traditionally employed as a treatment [17], [18]. Over the past decade, extensive studies have explored the ethnomedicinal uses of *E. longifolius* for diarrhea within the Bromo Tengger Semeru National Park region [19─24]. This national park is situated east of the provincial capital Surabaya, spanning 7°54’ to 8°55’13’S latitude and 112°5’ to 113°04’E longitude. Covering 503 km², the park features hilly and steep mountainous terrain, including Mount Semeru, Java’s highest peak at an altitude range of 750–3676 m above sea level. This fruit is empirically used to manage diarrhea, primarily due to its phenolic content, including tannins, flavonoids, and alkaloids [19].

The relationship between fruit ripeness levels and the clinical effectiveness of bioactive compounds warrants further investigation to ensure safer and more effective therapeutic applications of these plants. These bioactive compounds exhibit antidiarrheal activity through complementary mechanisms: tannins act as astringents that reduce intestinal secretion and protein binding, while flavonoids inhibit intestinal motility and disrupt bacterial cell walls [25─29]. The antidiarrheal-antibacterial activity of alkaloids is linked to their ability to inhibit dihydrofolate reductase, disrupt nucleic acid synthesis, impair Z-ring formation and cell division, reduce oxygen consumption as respiratory inhibitors, and compromise bacterial membrane integrity [30]. Notably, the concentration of these compounds varies with fruit ripeness, with unripe fruit containing higher levels of tannins [31], [32]. Importantly, the concentration of these compounds varies with fruit ripeness. Unripe fruit contains higher levels of tannins, which are known to contribute to the clinical effectiveness of these bioactive compounds. This highlights the importance of fruit ripeness as a factor influencing therapeutic outcomes.

Despite its traditional use, the antidiarrheal potential of *E. longifolius* remains underexplored, particularly regarding its antibacterial activity and phytochemical profile. This study aims to address this gap by evaluating the efficacy of Jambu Wer extracts with various polarities (ethanol, n-hexane, ethyl acetate, and chloroform) in vitro, in addition the phytochemical profile was also detected. The findings are expected to offer critical insights into the therapeutic potential of Jambu Wer, supporting its advancement as one of Fitofarmaka -Indonesia’s highest classification for traditional medicines- and laying the groundwork for the discovery of new antidiarrheal agents.

Materials and Methods

Plant Material

Elaeocarpus longifolius fruits were harvested from Ngadas Village (Malang) at an immature ripeness stage, approximately 3-4 weeks after flowering (Figure 1). The fruits were immediately washed with running water to remove contaminants. Subsequently, the washed fruits were subjected to hot air drying at temperatures ranging from 40─50 °C for 48 hours, or until a stable moisture content was reached. This low-temperature drying method was chosen to avoid the degradation of

bioactive compounds that could occur at higher temperatures. Following the drying process, the fruits were air-dried for an additional 24 hours to ensure the removal of any remaining moisture. The dried fruits were then ground into a fine powder using a grinder. The moisture content of the powder was measured using a moisture content analyzer, ensuring it was below 10%.

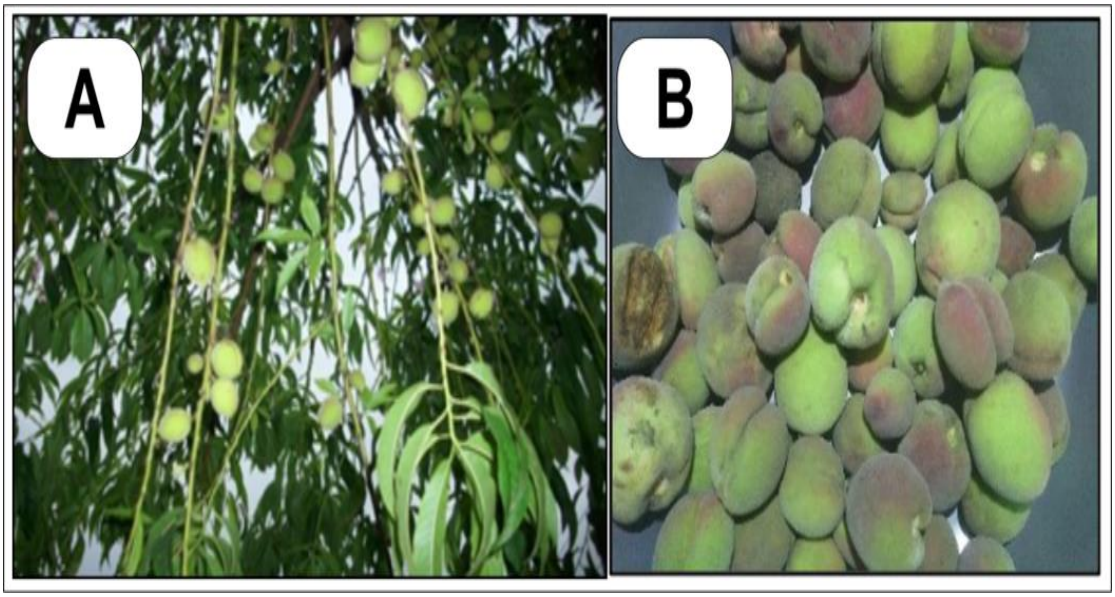

Figure 1. Plant material of *Elaeocarpus longifolius*. (A) Immature fruit with stems and leaves; B) Fruits at an early ripening stage, approximately 3–4 weeks after flowering.

Preparation of Plant Extracts

For each extraction, 200 g of plant powder was dissolved in 2000 mL of solvent (resulting in a 1:10 (w/v) ratio), using four different solvents with varying polarity: ethanol, n-hexane, ethyl acetate, and chloroform. The maceration process was carried out over three 24-hour cycles, with the solvent replaced at predetermined intervals. All procedures were conducted in sealed, light-resistant containers to protect the bioactive compounds from degradation. After the maceration process, the solvent was evaporated using a rotary evaporator at 50°C and 500 rpm until a thick extract was obtained. This method ensured the preservation of the extracts' bioactive compounds for further analysis.

Antibacterial Activity Test

The antibacterial activity of the extracts was evaluated using the agar disk-diffusion method following the CLSI guidelines and Ramzi *et al* [33], cultures of *E. coli* and *S. dysenteriae* (1 mL each) were introduced into sterile petri dishes. Melted and cooled Mueller-Hinton Agar (MHA) was poured into the dishes containing the bacterial inoculum and mixed thoroughly. Once solidified, wells with a diameter of 6 mm were created in the agar using a sterile borer. Each well was filled with 30 µL of extracts (ethanol, n-hexane, ethyl acetate, and chloroform) at a concentration of 40 mg/mL. Chloramphenicol (0.5 mg/mL) served as the positive control, while 10% DMSO was used as the negative control. The plates were refrigerated for 30 minutes to facilitate proper diffusion of the extracts into the agar, followed by incubation at 37°C for 24 hours. The zones of inhibition around the wells were measured to determine antibacterial activity. The antibacterial tests were performed in triplicate for each extract and control preparation to ensure the reliability and reproducibility of the results.

The data collected were analyzed statistically using one-way ANOVA to identify significant differences, with a

threshold for significance set at $P < 0.05$. The analysis was conducted using SPSS software (version 22, IBM Corporation, NY, USA). Results are expressed as mean values ± standard deviation to ensure clarity and precision in data presentation.

Phytochemical Detections

The phytochemical screening of *E. longifolius* extracts was conducted to detect bioactive compounds, including flavonoids, tannins, and alkaloids. For flavonoid detection, 1 mL of the extract was combined with three drops of concentrated hydrochloric acid and magnesium sulfate powder in a test tube. The development of a pink coloration within minutes confirmed the presence of flavonoids. Tannin detection involved diluting the extract with distilled water and adding a few drops of 1% ferric chloride ($FeCl_3$) solution, where a bluish-green color indicated tannin presence. Alkaloids were identified by mixing 2–3 drops of the extract with five drops of concentrated ammonia, followed by the addition of 2N sulfuric acid. The solution was shaken to separate layers, which were divided into two portions. One portion was tested with Mayer's reagent and the other with Dragendorff's reagent, with a precipitate in either test confirming alkaloid presence [34].

Thin-layer chromatography was employed to further analyze flavonoids, tannins, and alkaloids. For alkaloid testing, the extract was alkalinized with 28% NH_4OH and extracted with chloroform, followed by evaporation and methanol dissolution. The residue was applied to Kiesel Gel GF 254 plates, with a mobile phase of chloroform-ethyl acetate (1:1). Spots were visualized using Dragendorff reagent, with orange spots indicating alkaloids. Flavonoid analysis involved dissolving the extract in n-hexane, followed by ethanol treatment, and applying the solution to Kiesel Gel GF 254 plates. A mobile phase of chloroform-acetone-formic acid (6:6:1) was used, and yellow spots visualized with staining agents confirmed flavonoids. For tannins, 0.3 g of extract was dissolved in hot distilled water with 10% NaCl, stirred, filtered, and analyzed using a mobile phase of chloroform-ethyl acetate-formic acid (0.5:9:0.5). Black spots on TLC plates indicated the presence of tannins and polyphenols [35].

Results and Discussion

The immature fruits of *E. longifolius* were collected from Ngadas (Malang), a region identified as one of the "Tengger Villages", where the plant is known to grow abundantly [25], [36]. The fresh fruit material initially weighed 4000 g but was reduced to 900 g after being processed into a fine powder. The powder's moisture content was measured through three separate tests, resulting in an average of 4.29% ± 0.14. The low moisture content, significantly below the 10% threshold, ensures the stability of the powder, halts enzymatic activity, and reduces the risk of microbial contamination [37], [38].

The extract yield results highlighting the variations based on the solvent type. Among the solvents used, ethanol demonstrated the highest efficiency, yielding 16.6% (equivalent to 33.2 g of extract from 200 g of powder). In comparison, the yields for chloroform, ethyl acetate, and n-hexane extractions were significantly lower, each producing 5.8%, 5.3%, and 5.3%, respectively. These findings highlight the critical role of solvent polarity in the extraction process [39], [40]. Ethanol as a versatile solvent, effectively extracts both polar and non-polar phytochemicals [41–43].

The antibacterial activity of *E. longifolius* fruit extracts were evaluated against *E. coli* and *S. dysenteriae* using the agar disk-diffusion methods, yielding varying inhibition zone results depending on the solvent. The agar disk-diffusion method is widely recognized for its simplicity, cost-effectiveness, and ability to assess multiple antimicrobial agents simultaneously, provides straightforward

interpretation, making it a preferred tool for initial screenings. Moreover, this method demonstrates a strong correlation between *in vitro* data and in vivo data, underscoring its reliability. These findings supports the potential of *E. longifolius* extracts as antidiarrheal candidates, laying a robust foundation for further in vivo testing and therapeutic development [44].

Against *E. coli*, the ethanol extract demonstrated an average inhibition zone of 20.78 ± 0.64 mm, while the ethyl acetate extract showed a smaller inhibition zone of 2.50 ± 0.40 mm. Chloroform and n-hexane extracts exhibited average inhibition zones of 5.57 ± 0.89 mm and 9.40 ± 1.10 mm, respectively. Chloramphenicol, used as the positive control, produced a significantly larger inhibition zone of 30.84 ± 0.94 mm, whereas DMSO, the negative control, showed no antibacterial activity, with no observable inhibition zones (Table 1 and Figure 2). For *S. dysenteriae*, the ethanol extract achieved an inhibition zone of 21.45 ± 0.87 mm, with the chloroform extract showing a zone of 5.57 ± 0.89 mm. No inhibition zone was observed for the ethyl acetate extract, while the n-hexane extract displayed an average inhibition zone of 9.40 ± 1.10 mm. Chloramphenicol exhibited a markedly larger inhibition zone of 30.84 ± 0.94 mm as the positive control, while DMSO again showed no activity (Table 2 and Figure 3).

Both *E. coli* and *S. dysenteriae* are gram-negative bacteria with cell walls rich in non-polar lipopolysaccharides [45], making them inherently more resistant to the penetration of phytochemical compounds [46]. Despite this, the phytochemical constituents of *E. longifolius* such as flavonoids, tannins, and alkaloids demonstrated notable antibacterial activity. This indicates the promising potential of *E. longifolius* extracts in targeting diarrhea-causing pathogens, highlighting their suitability as candidates for antidiarrheal therapeutics.

Table 1. Inhibition zone of *E. longifolius* extracts against *E. coli*

Sample	Inhibition zone (mm ± SD)	Classification levels [44]
Ethanol extract	20.78 ± 0.64	Very strong activity
Chloroform extract	5.57 ± 0.89	Medium activity
Ethyl acetate extract	2.50 ± 0.40	Weak activity
n-Hexane extract	9.40 ± 1.10	Medium activity
Positive control (Chloramphenicol)	30.84 ± 0.94	Very strong activity
Negative control (DMSO)	Not detected	-

Table 2. Inhibition zone of *E. longifolius* extracts against *S. dysenteriae*

Sample	Inhibition zone (mm ± SD)	Classification levels [44]
Ethanol extract	21.45 ± 0.87	Very strong activity
Chloroform extract	8.26 ± 0.46	Medium activity
Ethyl acetate extract	Not detected	-
n-Hexane extract	15.30 ± 1.30	Strong activity
Positive control (Chloramphenicol)	29.34 ± 0.54	Very strong activity
Negative control (DMSO)	Not detected	-

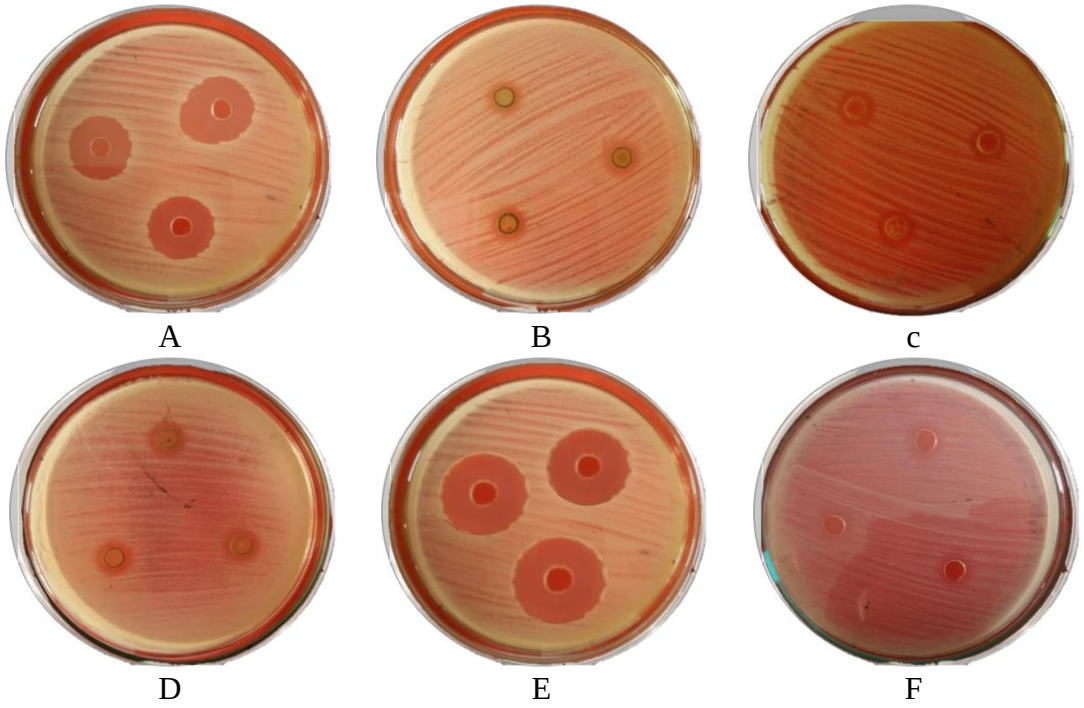

Figure 2. The results of the antibacterial activity test of *E. longifolius* extracts against *E. coli*. A) Ethanol extract; B) Chloroform extract; C) Ethyl acetate extract; D) n-Hexane extract; E) Positive control (chloramphenicol); and F) Negative control (DMSO).

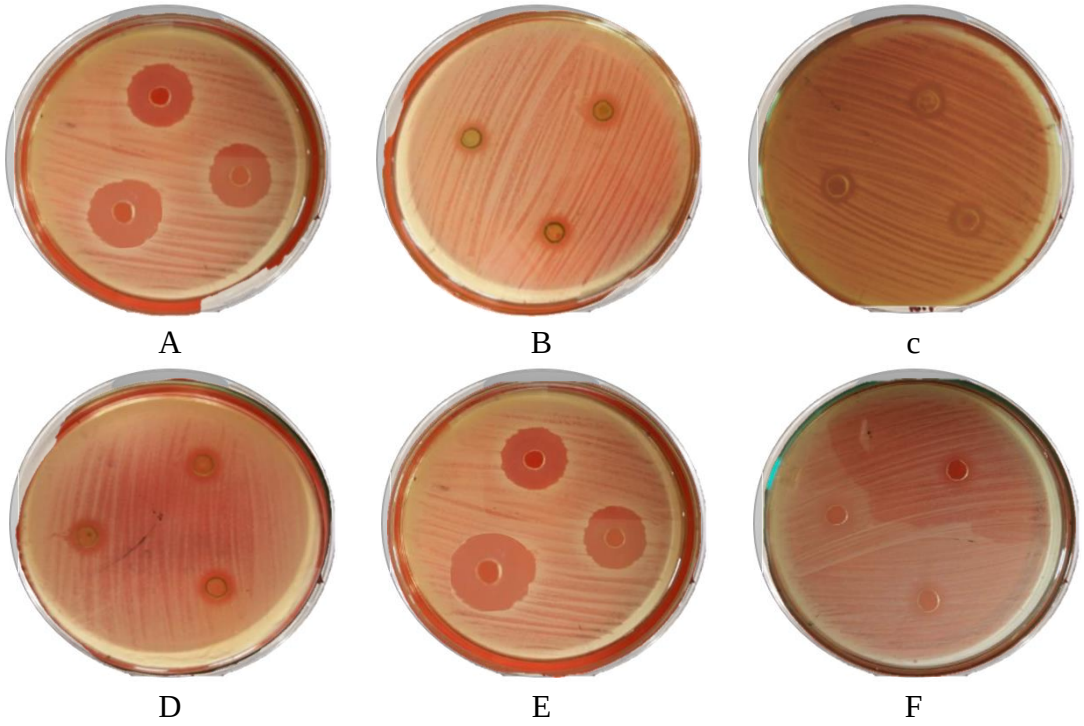

Figure 2. The results of the antibacterial activity test of *E. longifolius* extracts against *S. dysenteriae*. A) Ethanol extract; B) Chloroform extract; C) Ethyl acetate extract; D) n-Hexane extract; E) Positive control (chloramphenicol); and F) Negative control (DMSO).

Although the antibacterial activity of the ethanol extract of *E. longifolius* against diarrhea-causing bacteria was statistically different from the positive control, it still exhibited very strong antibacterial activity (>20 mm). Inhibition zones were classified as weak (<5 mm), medium (5–10 mm), strong (10–20 mm), and very strong (>20 mm) [47]. Ethanol extracts from various species within the Elaeocarpaceae family have also exhibited remarkable antibacterial activity, further highlighting their potential as sources of bioactive compounds [48]. Ethanol extracts of *E. ganitrus* have demonstrated significant antibacterial activity against *Bacillus subtilis*, *Bacillus megaterium*, *Pseudomonas aeruginosa*, and *Salmonella typhi*, showcasing their broad-spectrum efficacy [47]. Previous studies have also validated the antibacterial activity of ethanol extracts derived from *E. ganitrus*, further supporting the therapeutic potential of this species [34], [49], [50]. The ethanol extract of *E. floribundus* and *E. recurvatus* fruit has demonstrated notable antibacterial activity against various food-borne bacteria, highlighting its potential as a natural antimicrobial agent in food safety applications [51], [52]. Biswas *et al* [49] and Fernando *et al* [53], evaluated the antimicrobial efficacy of ethanol extracts of *E. serratus*, demonstrating its significant activity against various microbial strains.

Ethanol extracts from various species within the Elaeocarpaceae family have also demonstrated antidiarrheal properties. For instance, *E. serratus* has shown promising antidiarrheal activity in a mouse model, highlighting its therapeutic potential in gastrointestinal disorders [54]. *E. floribundus* has also demonstrated significant potential as a plant-based antidiarrheal medicine [55]. The therapeutic potential of *E. longifolius* as an antidiarrheal agent is equally promising, aligning with the broader therapeutic capabilities of Elaeocarpaceae species in managing gastrointestinal issues.

The phytochemical screening of *E. longifolius* extracts revealed that the ethanol extract was the most effective solvent, detecting the presence of flavonoids, tannins, and alkaloids. This aligns with the overall strength of ethanol as a solvent for extracting a wide range of bioactive compounds. The chloroform extract, which contained flavonoids and alkaloids but lacked tannins, suggests that chloroform may selectively extract specific compounds. Similarly, the ethyl acetate extract, which only revealed flavonoids, and the n-hexane extract, which revealed flavonoids and alkaloids but no tannins, further reinforce the differences in solvent efficacy and their selective extraction properties (Table 3).

Table 3. Phytochemical profile of *E. longifolius* extracts using phytochemical screening assay with reagents

Extract	Phytochemical compounds		
	Flavonoids	***Tannins***	***Alkaloids***
Ethanol	Detected	Detected	Detected
Chloroform	Detected	Not detected	Detected
Ethyl acetate	Detected	Not detected	Not detected
n-Hexane	Detected	Not detected	Detected

The data presented in Table 4, which outlines the phytochemical profile of *E. longifolius* extracts through thin-layer chromatography (TLC), further substantiates the findings from the preliminary screening assay. The ethanol extract, which exhibited the presence of flavonoids, tannins, and alkaloids in both TLC and the screening assay, confirms its comprehensive phytochemical

composition. This consistency underscores the ethanol extract's potential as a source of bioactive compounds. The chloroform extract demonstrated the presence of flavonoids and alkaloids but lacked tannins, a result that aligns with the initial screening assay, reinforcing the specific phytochemical characteristics of this extract. The ethyl acetate extract showed only flavonoids, with no tannins or alkaloids detected, confirming the results from the screening assay. Similarly, the n-hexane extract, which contained flavonoids and alkaloids but no tannins, is consistent with both the TLC and screening assay data, further validating the reliability of these methods in profiling the phytochemical content of the extracts. These findings collectively support the characterization of each extract's bioactive compounds, reinforcing their potential therapeutic applications.

Table 4. Phytochemical profile of *E. longifolius* extracts with thin-layer chromatography test

Extracts	Phytochemical compounds		
	Flavonoids	***Tannins***	***Alkaloids***
Ethanol	Detected	Detected	Detected
Chloroform	Detected	Not detected	Detected
Ethyl acetate	Detected	Not detected	Not detected
n-Hexane	Detected	Not detected	Detected

We revealed ethanol extract of *E. longifolius* detecting flavonoids, tannins, and alkaloids. Flavonoids contribute to gastrointestinal health by influencing the intestinal barrier, immune system, nutrient digestion and absorption, and microbiota growth and metabolism, primarily through mechanisms that maintain mucosal integrity and activate signaling pathways in intestinal epithelial cells to prevent pathogen invasion [26]. Chen *et al* [56], demonstrated that baicalin protects intestinal epithelioid cell 6 (IEC-6) cells and intercellular tight junctions from LPS-induced injury by inhibiting inflammatory cytokine production. Clinical studies have highlighted the effectiveness of tannins in treating acute diarrhea, their antidiarrheal effects in patients with Crohn's disease, and their modest protective role against traveler's diarrhea when combined with ethacridine lactate [57]. Mechanistically, tannins inhibit CFTR-dependent chloride secretion in cell models such as Caco-2, FRT, and T84, and tannic acid specifically targets TMEM16A, a calcium-activated chloride channel [58]. Additionally, tannic acid has been found to enhance mucosal resistance during infections by reducing intestinal permeability changes and provides protection against oxidative stress-induced cell death [59]. Alkaloids exhibit antidiarrheal and antibacterial activities through multiple mechanisms, including inhibition of dihydrofolate reductase, disruption of nucleic acid synthesis, impairment of Z-ring formation and cell division, reduction of oxygen consumption as respiratory inhibitors, and disruption of bacterial membrane integrity. Notably, alkaloids like piperine are highly effective as antidiarrheal agents [30].

The latest research by Bhagawan *et al* [19], revealed that the ethanol extract of *E. longifolius* fruit contains a diverse array of phytochemicals. Among the flavonoids, peonidin (21.91 %) emerged as the dominant constituent. Significant alkaloids identified include piperine (11.65 %), D-phenylalanine-benzoxazole (15.89 %), and piperidine. Additionally, L-serine, linked to tannin pathways, contributes to the extract's overall phytochemical profile.

Elaeocarpaceae species are renowned for their rich phytochemical diversity, encompassing alkaloids, flavonoids, glycosides, tannins, triterpenes, fatty acids, ellagic acid derivatives, and

cytotoxic compounds [48]. Several studies have identified specific phytochemicals in Elaeocarpaceae fruits. For instance, the fruits of *E. oblongus* have been reported to contain fructose, sucrose, flavonoids, tannins, steroids, phenolic compounds, and fatty acids [60]. *E. floribundus* fruits are known to contain cardiac glycosides, anthraquinone glycosides, steroids, terpenoids, and quinones [52], [61], [62]. Additionally, the fruits of *E. chelonimorphus* have been reported to contain triterpenes [61], while *E. dentatus* fruits are rich in fatty acids such as palmitic, oleic, linoleic, hexadecenoic, and linolenic acids [63]. Furthermore, the fruits of *E. tuberculatus* have been reported to contain a wide range of phytochemicals, including alkaloids, steroids, saponins, phenols, flavonoids, coumarins, glycosides, proteins, gums, mucilage, triterpenoids, tannins, and quinones [64]. The therapeutic potential of the ethanol extract of *E. longifolius* fruits as an antidiarrheal agent is equally promising, supported by phytochemical compounds such as flavonoids, tannins, and alkaloids.

Conclusion

The ethanol extract of *Elaeocarpus longifolius* fruits exhibited significant in vitro antibacterial activity against *E. coli* and *S. dysenteriae*, two prominent pathogens associated with severe diarrhea. Phytochemical analysis revealed the presence of alkaloids, flavonoids, and tannins in the ethanol extract, compounds known for their bioactive properties. These findings highlight the potential of ethanol extract of *E. longifolius* fruit as a promising candidate for the development of new *Fitofarmaka* targeting diarrheal diseases.

Acknowledgments

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Conflict of interest

We declare that there is no conflict of interest.

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