

JURNAL METAMORFOSA
Journal of Biological Sciences
eISSN: 2655-8122
<https://ejournal3.unud.ac.id/index.php/metamorfosa/>

**Efektivitas Ekstrak Daun Kayu Manis (*Cinnamomum burmannii* Blume) Menghambat
Pertumbuhan Jamur *Candida albicans* ATCC 10231 Penyebab Kandidiasis**

**Antifungal Potential of Cinnamon Leaf Extract Against *Candida albicans* ATCC 10231
Causing Candidiasis**

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ABSTRACT

Candida albicans is an opportunistic pathogenic fungus that causes candidiasis. *C. albicans* infections can lead to resistance due to a progressive increase of *C. albicans* infections or long-term exposure to conventional antifungal agents. Alternative treatments for *C. albicans* can be carried out using natural ingredients with antifungal potential. This study aims to analyze the effectiveness of the ethanol extract of cinnamon leaves (*Cinnamomum burmannii* Blume) in inhibiting the growth of *C. albicans* ATCC 10231. A Completely Randomized Design (CRD) method was employed in this study. Extraction was performed by maceration using 96% ethanol, followed by separation and fractionation. Antifungal activity was tested using the well diffusion method, followed by a Minimum Inhibitory Concentration (MIC) test. Gas Chromatography Mass Spectrometry (GC-MS) analysis was performed on the fraction with the highest inhibitory activity, while Scanning Electron Microscopy (SEM) analysis was conducted on *C. albicans* cells after extract treatment. The MIC test results from this study indicate that cinnamon leaf extract with 1% ethanol concentration has the potential to inhibit the growth of *C. albicans*, with an inhibition zone 8.215 ± 0.031 mm. GC-MS analysis revealed the presence of bioactive compounds such as cinnamaldehyde, hexadecanoic acid ethyl ester, and 9,12-octadecadienoic acid ethyl ester which function as antifungal agents. The SEM results for fraction 5 revealed damage to the cells morphological structure, including changes in cell shape, damage to the cell walls, and cell lysis. This indicates that ethanol extract of cinnamon leaves is capable of inhibiting the growth of *C. albicans* in vitro.

Keywords: *Candida albicans*, *Cinnamomum burmannii*, Minimum Inhibitory Concentration (MIC), Gas Chromatography Mass Spectrometry (GC-MS), Scanning Electron Microscopy (SEM)

INTISARI

Candida albicans merupakan jamur oportunistik penyebab kandidiasis. Infeksi *C. albicans* dapat menyebabkan resistensi akibat peningkatan jumlah kasus infeksi *C. albicans* yang terus-menerus atau paparan jangka panjang terhadap agen antijamur konvensional. Pemanfaatan senyawa alami yang memiliki aktivitas antijamur menjadi salah satu pendekatan dalam pengembangan terapi alternatif untuk mengatasi infeksi *C. albicans*. Penelitian ini bertujuan untuk menilai efektivitas ekstrak etanol daun kayu manis (*Cinnamomum burmannii* Blume) dalam menghambat pertumbuhan *C. albicans* ATCC 10231. Metode Rancangan Acak Lengkap (RAL) digunakan, dengan enam perlakuan dan empat pengulangan. Ekstraksi meliputi proses maserasi menggunakan etanol 96%, dilanjutkan partisi dan fraksinasi. Aktivitas antijamur diuji menggunakan metode difusi sumuran dan dilanjutkan dengan penentuan nilai Minimum Inhibitory Concentration (MIC). Analisis Gas Chromatography Mass Spectrometry (GC-MS) dilakukan pada fraksi dengan aktivitas hambat tertinggi, sedangkan analisis

Scanning Electron Microscopy (SEM) dilakukan pada sel *C. albicans* setelah perlakuan ekstrak. Berdasarkan hasil analisis MIC, ekstrak etanol daun kayu manis pada konsentrasi 1% menunjukkan aktivitas penghambatan terhadap pertumbuhan *C. albicans*, yang ditunjukkan oleh terbentuknya zona hambat dengan diameter 8.215 ± 0.031 mm. Analisis GC-MS menunjukkan keberadaan senyawa bioaktif seperti *cinnamaldehyde*, *hexadecanoic acid ethyl ester*, dan *9,12-octadecadienoic acid ethyl ester* yang berperan sebagai antijamur. Hasil SEM pada fraksi 5 memperlihatkan terjadinya kerusakan struktur morfologi sel berupa perubahan bentuk sel, kerusakan dinding sel, dan terjadinya lisis sel. Hal ini menunjukkan bahwa ekstrak etanol daun kayu manis mampu menghambat pertumbuhan *C. albicans* secara *in vitro*.

Keywords: *Candida albicans*, *Cinnamomum burmannii*, *Minimum Inhibitory Concentration* (MIC), *Gas Chromatography Mass Spectrometry* (GC-MS), *Scanning Electron Microscopy* (SEM)

INTRODUCTION

Candidiasis is a fungal infection that affects body mucosa, particularly the vaginal mucosa and oral cavity. This infection occurs when the balance between fungi, mucosal tissues, and the host defense system is disrupted. This result supports the statement by Lopez and Leonakis (2022) that *Candida albicans* commonly exists as a commensal microorganism in humans but may become pathogenic when host immune defenses are weakened, allowing fungal invasion through epithelial tissues and dissemination into deeper sites. Vulvovaginal candidiasis is the most common form of candidiasis, characterized by symptoms such as pruritus, abnormal vaginal discharge, vulvar erythema, and excoriation. Ribeiro et al. (2019) reported that vulvovaginal candidiasis is a mucocutaneous infection caused by the overgrowth of *C. albicans* in the genital tract.

Epidemiological studies indicate that approximately 70–75% of women experience at least one episode of vulvovaginal candidiasis (VVC) during their lifetime, while 5–9% develop recurrent vulvovaginal candidiasis (RVVC), characterized by three or more symptomatic episodes occurring within a 12-month period (Papon and Dijek, 2021; Zhu and Guo, 2026). A study conducted by McKloud et al. (2021) using a collection of 100 clinical isolates (40 of which were obtained from women with RVVC and 60 from healthy women) found that 73% of the *Candida* species were isolated from women with RVVC.

C. albicans is an opportunistic fungal pathogen with significant virulence potential, largely attributed to its ability to undergo morphological transition between yeast and hyphal forms. The yeast phase contributes to systemic dissemination through the bloodstream, whereas the hyphal form promotes tissue invasion and enhances resistance against phagocytosis by host immune cells. Candidiasis treatment generally involves synthetic antifungal agents such as nystatin, ketoconazole, and miconazole. However, prolonged use may lead to antifungal resistance. Hossain et al. (2022) reported that resistance of *C. albicans* to antifungal agents continues to increase due to long-term drug exposure. In a study conducted by Hasanbeigi et al. (2015), which included 149 samples that tested positive in culture, the resistance rates of various *Candida sp.* to nystatin, fluconazole, ketoconazole, and itraconazole were found to be 6%, 37%, 37.5%, and 47%, respectively. On the other hand, a study by Maharani et al. (2020) on 26 *Candida sp.* isolates on oral candidiasis with HIV/AIDS revealed varying patterns of antifungal resistance, with resistance to ketoconazole, nystatin, and fluconazole at 10.7%, 0%, and 46%, respectively. This variation may be attributed to differences in antifungal drug exposure, as well as genetic diversity among *Candida* species and strains across different geographical regions (Hasanbeigi et al., 2015).

The emergence of increasing resistance to antifungal agents has stimulated research into natural products as potential alternative therapeutic approaches for the management of candidiasis. One plant with potential as a natural antifungal agent is cinnamon (*Cinnamomum burmannii* Blume). The main component of cinnamon that acts as an antifungal agent is cinnamaldehyde, which belongs to the flavonoid group (Yuditha and Larasati, 2022). Flavonoid compounds can increase the permeability of fungal cell membranes by denaturing cellular proteins, thereby causing damage to the membrane

structure. Astika et al. (2022) stated that phenolic and tannin compounds play a role in inhibiting chitin synthesis and damaging fungal cell membranes, thereby inhibiting the growth of *C. albicans*.

Several previous studies have demonstrated that cinnamon leaves possess considerable antifungal activity. Darmadi et al. (2019) reported that cinnamon leaf extract obtained through methanol maceration at a 1:10 ratio for 48 hours exhibited a Minimum Inhibitory Concentration (MIC) value of 0.5% against *Pseudocercospora fijiensis*, indicating a strong inhibitory effect. Siagian and Lubis (2021) also reported that cinnamon leaf extract at a concentration of 10% produced an inhibition zone of 8.29 mm (medium category) against fungal isolates, which increased to 11.22 mm at a concentration of 20% (strong category).

Preliminary findings demonstrated that crude cinnamon leaf extract at a 100% concentration effectively inhibited the growth of *C. albicans*, producing an inhibition zone diameter of 25.55 mm, which was categorized as very strong antifungal activity. However, studies regarding the inhibitory mechanism of cinnamon leaf extract against *C. albicans* remain limited, particularly concerning the identification of active compounds and their effects on fungal cell morphology.

Based on these considerations, this study aimed to investigate the antifungal potential of cinnamon leaf extract (*Cinnamomum burmannii* Blume) against *Candida albicans* ATCC 10231 through Minimum Inhibitory Concentration (MIC) assessment, identification of bioactive compounds using Gas Chromatography–Mass Spectrometry (GC-MS), and evaluation of fungal cell morphological alterations by Scanning Electron Microscopy (SEM). The findings are expected to provide scientific evidence supporting the potential application of cinnamon leaves as a natural antifungal agent for candidiasis treatment.

MATERIALS AND METHODS

Time and Location

The research was carried out between June and November 2025. Cinnamon leaves were collected from Banjar Belok, Belok Village, Petang District, Badung Regency, Bali, located at coordinates 8.286114339513025° S and 115.24266550176648° E, at an elevation of approximately 1,500 m above sea level. *Candida albicans* ATCC 10231 was provided by the Biochemistry Laboratory, Biology Study Program, Faculty of Mathematics and Natural Sciences, Udayana University.

Cinnamon Leaf Preparation and Extraction

Cinnamon leaf samples were collected by purposive sampling from healthy mature plants, selecting leaves located at the fifth to ninth positions from the shoot tip. The leaves were washed, dried under ambient conditions, and powdered into simplicia. Extraction was then carried out by maceration with 96% ethanol for 48 hours. The resulting maceration filtrate was evaporated under reduced pressure using a rotary evaporator maintained at 50°C until a concentrated crude extract was produced.

Re-isolation of *C. albicans*

C. albicans was isolated by taking 1–2 loopfuls of fungal culture and inoculating them onto SDA medium using the 4-quadrant streak plating method. Confirmatory testing for *C. albicans* was performed using the Dalmau method on Corn Meal Agar (CMA). The media were incubated at 37°C for 5–7 days to allow fungal colonies to grow. The growth of pseudohyphae, chlamydospores, and blastospores was observed under a 40× microscope (Kaur et al., 2024). For biochemical confirmation, the isolate was inoculated into carbohydrate fermentation media containing glucose, maltose, sucrose, and lactose. Changes in the medium and gas formation were observed after incubation.

Antifungal Activity Assay of Cinnamon Leaf Extract Against *C. albicans*

The concentrations of the extract solutions prepared were 2%, 4%, 8%, and 10%. In this study, positive control solution was prepared by dissolving 335 µL of nystatin (100,000 IU) in 665 µL of aquadest, while the negative control used ethanol 96%. The antifungal activity assay of the crude extract was conducted using the well diffusion method. A fungal suspension was spread onto SDA

medium using a sterile cotton swab. Holes were made in the medium using a cork borer and then filled with the crude extract, positive and negative control solution. The Petri dishes were incubated at 37°C for 24 hours. The resulting inhibition zones were measured using a Vernier caliper, and the strength of the inhibition zones was interpreted (Safitri et al., 2020).

Minimum Inhibitory Concentration (MIC) Test

Antifungal activity testing was conducted using the well diffusion method against *C. albicans* ATCC 10231. MIC determination was performed using several extract concentrations to identify the minimum concentration capable of inhibiting fungal growth. The MIC values to be tested start at concentrations of 1%, 2%, 3%, 4%, and 5%. The test will be conducted by inoculating a *C. albicans* suspension into SDA medium using a cotton swab; then, five wells will be prepared, into which each concentration will be added. The samples were incubated at 37°C for 24 hours. Inhibitory zones formed and were then observed for each concentration. The lowest concentration represents the MIC of the extract used. The dilution of the extract for the MIC test was calculated using the following formula: $M_1V_1 = M_2V_2$ (Saridewi et al., 2017). In this study, the Federer formula (Indratama, 2019) was used to determine the number of repetitions.

Fractionation of Cinnamon Leaf Extract

A 5-gram sample of cinnamon leaf extract was loaded into a column containing silica gel 60 (0.2–0.5 mm) as the stationary phase. A mobile phase composed of n-hexane, ethyl acetate, and ethanol was eluted through the chromatography column to separate the sample components into multiple fractions, which were subsequently collected in 50-mL vials based on volume. Subsequently, the inhibitory activity of each fraction against *C. albicans* was evaluated, and the fraction exhibiting the highest antifungal activity was further subjected to secondary metabolite analysis using GC–MS (Puspita et al., 2019).

Gas Chromatography-Mass Spectrometry (GC-MS) Analysis

GC–MS analysis was performed by injecting 1 µL of the sample into a system fitted with a CP–Sil 5 CB glass capillary column (25 m length, 0.25 mm internal diameter, and 0.25 µm film thickness). The chromatographic separation was achieved under a programmed oven temperature from 70°C to 270°C at a ramp rate of 10°C/min. Helium served as the carrier gas with a pressure of 12 kPa, a total flow rate of 30 mL/min, and a split injection ratio of 1:50. The GC–MS identification process will yield bioactive compounds, which can be observed as peaks on the chromatogram based on the results of chromatography and mass spectrometry (MS), as determined from the mass spectra corresponding to the molecular weights of each bioactive compound (Darmadi et al., 2021; Maulidya et al., 2018).

Scanning Electron Microscope (SEM) Analysis

Scanning electron microscope (SEM) analysis began by examining the surface of the treated test media in the clear zone and the zone colonized by *C. albicans*. The treatments selected for SEM observation were the negative control and the best-performing treatment group capable of inhibiting the growth of *Candida albicans*. Samples measuring approximately 1 × 1 cm were fixed in 4% glutaraldehyde for 12–48 h and subsequently rinsed with osmium tetroxide for 2 h. The samples were dehydrated using absolute alcohol for 10 min, followed by alcohol concentrations of 30%, 40%, 50%, 60%, 70%, 80%, 90%, and 100% for 15 min at each concentration. The dehydration procedure was repeated three times. The samples were then subjected to critical-point drying using CO₂ and coated with platinum using a desk sputter coater. SEM observations were performed at an accelerating voltage of 10 kV (Ganapathy et al., 2021).

Data Analysis

Statistical analysis of the inhibition zone diameter measurements was performed using a one-way analysis of variance (ANOVA) test in IBM SPSS Statistics to determine significant differences among treatment groups. Prior to performing the One-way ANOVA test, the data were subjected to

normality and homogeneity tests as prerequisites for analysis. The distribution pattern of the collected data was examined through a normality test. Normality was confirmed when the statistical analysis showed a significance value higher than the 5% significance threshold ($p > 0.05$). A homogeneity test was then performed to evaluate the equality of variances among treatments. The data were regarded as homogeneous when the significance value was greater than 0.05 ($p > 0.05$). When the data satisfied both normality and homogeneity assumptions, a One-way ANOVA test was subsequently conducted to determine the effect of cinnamon leaf extract treatments on the growth of *C. albicans* ATCC 10231.

RESULTS

Identification of *C. albicans* ATCC 10231

Identification of *C. albicans* ATCC 10231 was carried out macroscopically and microscopically to ensure the purity and characteristics of the isolate used in this study. Macroscopic observation on CMA media showed cream-white colonies with smooth surfaces and circular colony shapes. Microscopic observation revealed the presence of blastospores, pseudohyphae, and chlamydospores, which are characteristic features of *C. albicans*. Blastospores appeared round with polar budding, while pseudohyphae appeared elongated with clear septa. Chlamydospores were round, thick-walled, and located at the ends of pseudohyphae. These identification results are consistent with the characteristics of *C. albicans* reported by Bharathi (2018). The results of *C. albicans* identification are presented in Figure 1.

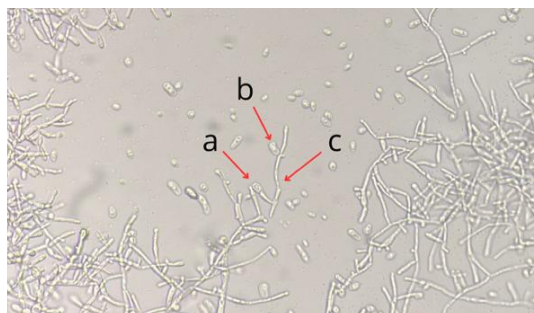


Figure 1. Microscopic morphology of *C. albicans* observed at 400× magnification after 5 days of incubation at 37°C. Description: (a) blastospore, (b) pseudohyphae, (c) chlamydospore

The biochemical confirmation showed positive fermentation reactions for glucose, maltose, and lactose, as indicated by changes in the color of the fermentation media. Gas formation was observed in the glucose fermentation test. The fermentation tests were incubated at 37°C for 24 hours. These findings were consistent with the identification of the *C. albicans* ATCC 10231 isolate used in this study.

The Effects of Cinnamon Leaf Extract on *C. albicans* ATCC 10231

Based on the inhibition zone diameter measurements obtained from the MIC assay, the 1% treatment concentration was determined as the minimum concentration capable of suppressing *C. albicans* growth, with an inhibition zone diameter of 8.215 ± 0.031^b mm. This inhibition response was classified as moderate activity. The results of the MIC test of cinnamon leaf extract against *C. albicans* are presented in Table 1.

The minimum inhibitory concentration (MIC) assay demonstrated that ethanol extract of cinnamon leaves exhibited inhibitory activity against *C. albicans*, with the lowest effective concentration determined at 1% (v/v) (Table 1). The MIC value can serve as an indirect indicator of the extract's toxicity level toward fungal growth. The MIC value of an extract is influenced by the type of fungus being tested, the content of active compounds in the crude drug obtained after extraction with a solvent, and the environmental conditions under which the crude drug used as the extract was collected (Suryaningsih et al., 2024).

Table 1. Minimum Inhibitory Concentration Determination Results of Cinnamon Leaf Extract (*C. burmannii*) Against *C. albicans*.

Treatment % (v/v)	Inhibition Zone Diameter (mm)	Inhibitory Category
Control (+)	22.470 ± 0.067 ^g	Very Strong
5	10.960 ± 0.024 ^f	Moderate
4	9.145 ± 0.042 ^e	Moderate
3	9.115 ± 0.031 ^d	Moderate
2	8.490 ± 0.066 ^e	Moderate
1	8.215 ± 0.031 ^b	Moderate
Control (-)	0.000 ± 0.000 ^a	Weak

Note: Control (+): Nystatin antifungal drops (1%); and Control (-): 96% ethanol. The values shown are the averages of four repetitions. Different letter annotations within the same column indicate statistically significant differences ($P \leq 0.05$) based on Duncan's test conducted after ANOVA analysis.

Evaluation of inhibition zones using the well diffusion method demonstrated concentration-dependent antifungal activity of cinnamon leaf extract against *C. albicans*, indicating its potential to suppress fungal growth. Statistical analysis revealed that the inhibition zone diameters obtained from each extract concentration had a significant effect on *C. albicans* growth ($P \leq 0.05$). Cinnamon leaf extract at a concentration of 10% exhibited moderate inhibition of *C. albicans* growth, while lower concentrations (8%, 4%, and 2%) displayed weaker inhibitory effects. The positive control consisting of 1% (v/v) nystatin drops demonstrated antifungal activity against *C. albicans*, producing an inhibition zone with a diameter of 21.840 ± 0.082 mm and classified within the strong inhibition category. Meanwhile, the negative control treatment with 96% ethanol showed no inhibitory effect against *C. albicans*. The statistical results of the disk diffusion assay evaluating the inhibitory effect of cinnamon leaf extract on *C. albicans* are shown in Table 2.

Table 2. Inhibitory activity test results of cinnamon leaf extract against *C. albicans* using the well diffusion method.

Treatment (% v/v)	Inhibition Zone Diameter (mm)	Inhibitory Category
Control (+)	21.840 ± 0.082 ^f	Very Strong
10	15.910 ± 0.057 ^e	Strong
8	11.915 ± 0.079 ^d	Strong
4	9.822 ± 0.434 ^c	Moderate
2	8.657 ± 0.015 ^b	Moderate
Control (-)	0.000 ± 0.000 ^a	Weak

Note: The values are expressed as the mean of four independent repetitions. Different letter annotations within the same column indicate statistically significant differences ($P \leq 0.05$) based on Duncan's test conducted after ANOVA analysis.

GC-MS Bioactive Compound Identification

GC-MS analysis was performed on fraction number 5, which exhibited the highest antifungal activity against *C. albicans*. The identification results revealed the presence of several bioactive compounds with potential antifungal activity, namely 2-Propenal, 3-phenyl- (cinnamaldehyde), 2-Methyl-3hydroxy-2,3-dihydrobenzofuranone, Hexadecanoic acid ethyl ester, 9,12-Octadecadienoic acid ethyl ester, and 2-Propen-1-ol, 3-phenyl-, acetate.

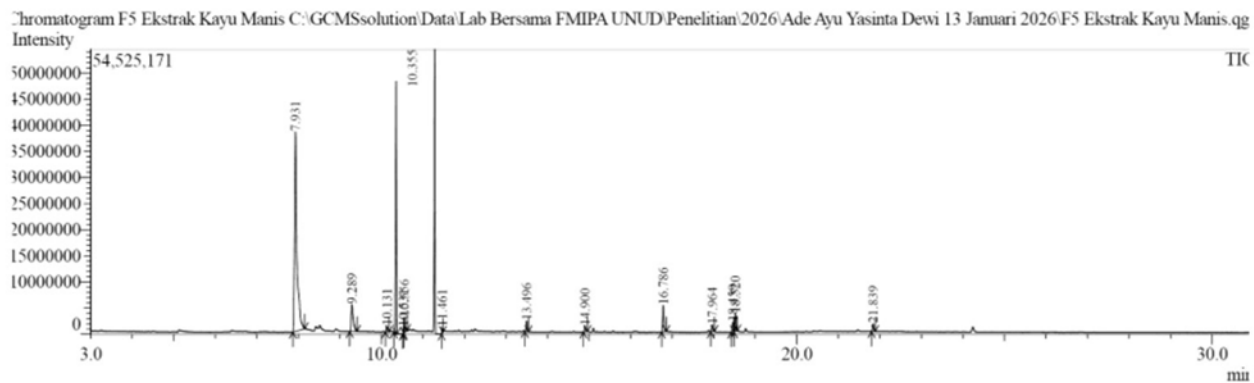


Figure 2. GC-MS Chromatogram of Fraction Number 5 of Cinnamon Leaf Extract

The analysis identified several chemical compounds based on their retention time (Rt), mass-to-charge ratio (m/z), and peak area. Several of the identified compounds have previously been reported to possess antimicrobial or antifungal potential. The identified compounds along with their reported biological activities are summarized in Table 3.

Table 1. Identification Results of Bioactive Compounds in Fraction Number 5 of Cinnamon Leaf Extract Using Gas Chromatography Mass Spectrometry (GC-MS)

No	Rt (menit)	Mass ion (m/z)	Area	Compound Name	Biological Activity
1.	7.929	131.00	31513797	2-Propenal, 3-phenyl-	Antimicrobial (Nilam et al., 2020)
2.	10.126	161.00	367405	11-Oxatetracyclo [4.2.1(2,5).1(3.9)]undec-7-	Antimicrobial (Qalalweh, 2025)
3.	10.354	43.00	10980928	2-Propen-1-ol, 3-phenyl-,acetate	Antimicrobial (Hariroh et al., 2025)
4.	10.555	147.00	274051	2-Methyl-3hydroxy-2,3-dihydro benzofuranone	Antimicrobial (Nath et al., 2021)
5.	13.496	97.00	754397	Oxalic acid, cyclohexylmethyl tridecyl ester	Antimicrobial (Graż, 2024)
6.	16.786	88.00	2030634	Hexadecanoic acid, ethyl ester	Antimicrobial (Mensah-agyei & Ayeni, 2020)
7.	18.459	67.00	274321	9,12-Octadecadienoic acid, ethyl ester	Antimicrobial (Onwuliri et al., 2020)
8.	18.520	55.00	441827	Ethyl Oleate	Antimicrobial (Vitro et al., 2021)
9.	21.838	149.00	792943	1,2-Benzenedicarboxylic acid, diisooctyl ester	Antimicrobial (Khalid et al., 2022)

Cinnamaldehyde is a major compound known to possess antifungal activity against the *Candida* genus. This compound exerts its antifungal activity by compromising cell membrane integrity and suppressing biofilm formation. Furthermore, cinnamaldehyde may interfere with ergosterol biosynthesis, leading to membrane disruption and the leakage of intracellular components.

Hexadecanoic acid ethyl ester and 9,12-Octadecadienoic acid ethyl ester belong to the fatty acid ester group known to exhibit antimicrobial activity. These compounds are capable of disrupting the lipid structure of the cell membrane, thereby affecting fungal membrane permeability. The compounds 2-Methyl-3hydroxy-2,3-dihydrobenzofuranone and phenylpropanoid derivatives also contribute to antifungal activity through disruption of cellular metabolism and damage to fungal cell structures.

SEM Analysis Results

Morphological observations using SEM, conducted on the strongest fraction without any treatment, showed that the cells were oval-shaped with smooth surfaces and exhibited traces of polar buds (Figure 3(a)). In the treated fraction, the opposite conditions were observed: the cells exhibited deformation and interconnection, cell surface shrinkage, traces of nonpolar buds, and cytoplasmic lysis (Figure 3(b)).

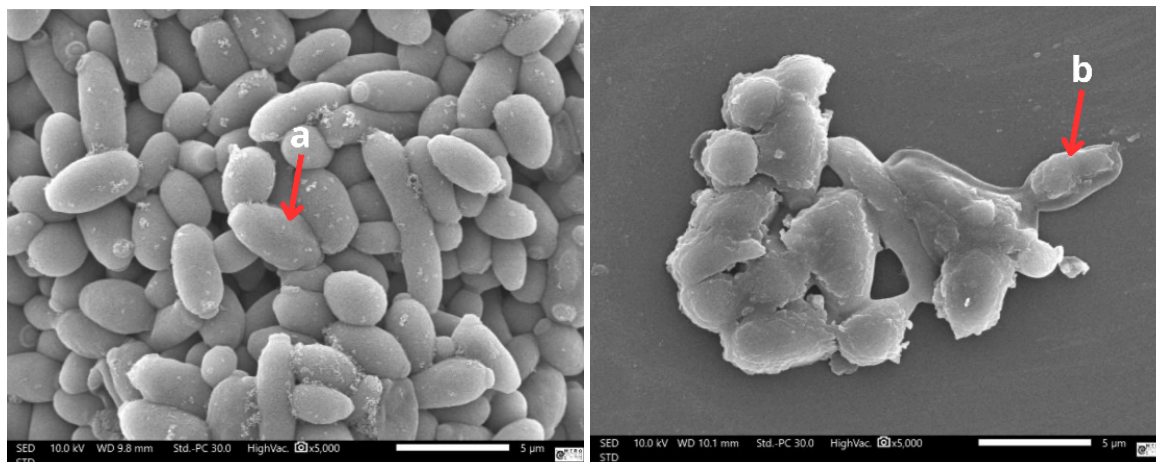


Figure 3. Results of morphological observations of *C. albicans* using SEM operating at 10 kV with a magnification of 5000x. (a): without treatment with the most potent fraction of cinnamon leaf extract. (b): after treatment with the most potent fraction of cinnamon leaf extract

DISCUSSION

Candida albicans is an opportunistic fungus causing candidiasis that is commonly found on human body mucosa, particularly in the oral cavity and female reproductive tract. Vulvovaginal candidiasis is reported to occur in approximately 7.7 million cases annually in Indonesia, with recurrent cases reaching 5 million per year. This infection generally occurs in women of reproductive age and is influenced by immune conditions, microbiota balance, and antifungal resistance.

Based on the obtained results, ethanol extract of cinnamon leaves demonstrated inhibitory activity against the growth of *C. albicans*, as evidenced by the significant differences in inhibition zone diameters among the tested treatment concentrations. The 10% (v/v) extract concentration showed the highest inhibitory activity with an inhibition zone diameter of 15.910 ± 0.057 mm; however, the inhibition zone diameter for the extract treatments did not exceed that of the positive control (Table 2). A previous study by Mersil and Alifia (2023) reported that a 75% ethanol extract of cinnamon (*Cinnamomum burmannii*) exhibited significant inhibitory activity against *C. albicans*, with an average inhibition zone diameter of 16.8 mm. A similar study by Padzil et al. (2025) on another cinnamon species, *Cinnamomum verum*, found that its leaf extract exhibited very strong antifungal activity against *C. albicans*, with an MIC of 0.039 mg/mL. The inhibitory activity of cinnamon leaf extract is presumed to be influenced by bioactive compounds capable of diffusing into the medium and disrupting fungal cell metabolism.

The minimum inhibitory concentration (MIC) assay conducted in this study revealed that ethanol extract of cinnamon leaves was capable of inhibiting the growth of *C. albicans*, with an MIC value of 1% (v/v) (Table 1). The MIC value can serve as an indirect indicator of the extract's toxicity level toward fungal growth. The MIC value of an extract is influenced by the type of fungus being tested, the content of active compounds in the crude drug obtained after extraction with a solvent, and the environmental conditions under which the crude drug used for the extract was collected (Suryaningsih et al., 2024). According to Darmadi et al. (2019), methanol extract derived from cinnamon leaves demonstrated inhibitory activity against *Pseudocercospora fijiensis*, with the MIC determined at a concentration of 0.5%.

Identification of active compounds using GC-MS revealed that fraction number 5 contained several compounds with potential antifungal activity, namely 2-Propenal, 3-phenyl-(cinnamaldehyde), 2-Methyl-3hydroxy-2,3-dihydrobenzofuranone, Hexadecanoic acid ethyl ester, 9,12-Octadecadienoic acid ethyl ester, and 2-Propen-1-ol, 3-phenyl-, acetate. Cinnamaldehyde is the major component of cinnamon essential oil known to possess antifungal activity against various fungal genera such as *Candida*, *Aspergillus*, and *Trichophyton*. This compound acts by disrupting cell membrane permeability, inhibiting biofilm formation, and reducing ergosterol content in fungal membranes. Membrane damage results in leakage of cytoplasmic contents and disruption of cellular metabolism. The compound 2-Methyl-3hydroxy-2,3-dihydrobenzofuranone belongs to the benzofuran derivative group reported to possess antimicrobial activity against fungal pathogens. This compound is known to interact with target proteins in *C. albicans*, thereby inhibiting cell growth and metabolism. In addition, the presence of Hexadecanoic acid ethyl ester and 9,12-Octadecadienoic acid ethyl ester also contributes to the antifungal activity of the extract. These compounds are fatty acid derivatives capable of disrupting the lipid arrangement of the cell membrane, thereby affecting membrane permeability.

The compound 2-Propen-1-ol, 3-phenyl-, acetate, which belongs to the phenylpropanoid group, is also known to possess antifungal activity through mechanisms involving disruption of fungal cell membranes and inhibition of cellular functions. The combination of these various bioactive compounds is presumed to enhance the antifungal activity of cinnamon leaf extract against *C. albicans*. Observations using Scanning Electron Microscopy (SEM) revealed significant morphological changes in *C. albicans* cells after treatment with cinnamon leaf extract. Untreated control cells appeared oval with smooth surfaces and distinct bud scars. In contrast, treated cells exhibited surface shrinkage, cell deformation, membrane damage, cell lysis, and leakage of cytoplasmic contents.

These observed morphological alterations suggest that cinnamon leaf extract may affect the structural integrity of the cell wall and cell membrane of *C. albicans*. Cinnamaldehyde is presumed to be the major compound responsible for this damage through interference with ergosterol synthesis and increased membrane permeability. Khan (2017) reported that cinnamaldehyde caused nuclear fragmentation and loss of cell wall integrity in *C. albicans*. Sajjad et al. (2013) also reported that phenyl aldehyde and phenylpropanoid compounds caused shrinkage, deformation, and vesicle lysis in *C. albicans* cells observed using SEM.

The findings from MIC, GC-MS, and SEM analyses in this study provide complementary evidence regarding the antifungal activity of cinnamon leaf extract against *C. albicans*. The MIC assay demonstrated the inhibitory potential of the extract against fungal growth, GC-MS analysis identified the presence of bioactive compounds with antifungal properties, and SEM observations confirmed morphological alterations in fungal cells following treatment with cinnamon leaf extract.

CONCLUSIONS

Candida albicans ATCC 10231 was successfully identified through macroscopic and microscopic observations characterized by the presence of blastospores, pseudohyphae, and chlamydospores. Cinnamon leaf ethanol extract derived from *Cinnamomum burmannii* showed antifungal efficacy against *C. albicans*, with an MIC value of 1%, indicating moderate inhibitory activity against fungal growth. GC-MS analysis identified several bioactive compounds with antifungal potential, including cinnamaldehyde, hexadecanoic acid ethyl ester, and 9,12-octadecadienoic acid ethyl ester. These compounds are presumed to contribute to antifungal mechanisms through disruption of fungal cell membrane integrity and inhibition of cellular metabolism. SEM observations confirmed morphological damage in *C. albicans* cells after treatment with cinnamon leaf extract, including cell deformation, cell wall damage, and cell lysis. The MIC, GC-MS, and SEM analyses collectively demonstrated that cinnamon leaf extract has the potential to be developed as a natural antifungal agent against *Candida albicans* causing candidiasis.

ACKNOWLEDGMENT

The authors sincerely acknowledge the invaluable guidance and support provided by the supervisors and colleagues of the Master Program in Biology, Faculty of Mathematics and Natural Sciences, Udayana University, throughout this research. Appreciation is also extended to the laboratory staff for their assistance with microbiological assays, GC–MS analysis, and SEM observations. This research was conducted without receiving any specific funding from public, commercial, or not-for-profit funding agencies

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