

DETERMINATION OF ALOIN AND ALOE-EMODIN IN PEEL, LATEX, AND GEL OF ALOE VERA AND THE ANTI-CANDIDA ALBICANS ACTIVITY OF CRUDE EXTRACT

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Abstract

Aloe vera is cultivated in several areas in Thailand, and its gel is used in the production of foods, drinks, medications, and cosmetic products. However, the harvested latex and discarded peels are often underutilized. Aloin and aloe-emodin, two major anthraquinone compounds present in *A. vera*, have been linked to several medicinal properties. Despite their importance, limited research has been conducted on the concentrations of aloin and aloe-emodin in the latex, discarded peel, and gel of *A. vera* cultivated in Thailand. This study aimed to assess the amounts of aloin and aloe-emodin in fresh latex, aloe peel extract, dry latex, and gel obtained from *A. vera* leaves. A comparative analysis was conducted on samples collected from different geographic regions and cultivation methods. Results revealed that the concentrations of aloin and aloe-emodin in dry latex ranged from 1.03-5.85 mg/g and 2.61-5.64 mg/g, respectively. In fresh latex, the concentrations were higher, ranging from 12.18-31.67 mg/g for aloin and 15.91-18.80 mg/g for aloe-emodin. In aloe gel, the concentrations ranged from 0.25-3.66 mg/g for aloin and 0.17-0.23 mg/g for aloe-emodin. Crude extracts from aloe peels contained 2.98-3.67 mg/g of aloin and 0.19-0.28 mg/g of aloe-emodin. No significant differences were observed between the levels of aloin and aloe-emodin in fresh and dry latex. Geographic location and cultivation method did not significantly influence compound concentrations in either latex or gel. Additionally, the crude aloe peel extract exhibited antifungal activity against *Candida albicans*, producing the largest inhibition zone at 30 mg/mL. Complete inhibition of fungal growth was achieved at 15 mg/mL after 24 h of incubation.

Keywords: Aloin; Aloe-emodin; *Aloe vera*; Aloe peel crude extract; *Candida albicans*; Determination; Latex; Thailand

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Introduction

Aloe vera Linne (synonym: *Aloe barbadensis*) is a succulent plant classified in the Liliaceae family (Edwards *et al.*, 2015). Although *A. vera* generally thrives in arid environments, it can also be cultivated in sandy loam or nutrient-rich soils (Rodríguez *et al.*, 2010). This plant is widely used for medicinal purposes (Bendjedid *et al.*, 2022), and the fleshy leaf gel is commonly processed into food and beverages. In Thailand, *A. vera* is cultivated in several regions, with major growing areas including Prachuap Khiri Khan, Ratchaburi, and Phetchaburi. These provinces possess soil characteristics favorable for the cultivation of *A. vera*.

Aloe latex contains several phytoconstituents with medicinal properties. Among these are anthraquinones such as aloin and aloe-emodin, which are recognized as active compounds in traditional medicine. Extracts from *A. vera* latex have demonstrated various biological activities, including antibacterial, antiparasitic, antioxidant, and anti-aging effects (Kumar *et al.*, 2017). According to the Thai traditional pharmacopeia, the dried latex of *A. vera* or *Aloe ferox* Mill is used as an ingredient in traditional medicines (Kitprathaung and Pianjing, 2023). The principal compound in aloe latex is aloin, an active constituent often combined with other herbs for medicinal purposes. In Thailand, dried latex containing aloin is referred to as “Yadum” in Thai, and “Aloin Preparata” in Latin. The term “Ya” translates to medicine, while “Dum” means black (Kitprathaung and Pianjing, 2023). Yadum, derived from dried *A. vera* latex, is a key active ingredient in Thai herbal laxatives used for treating constipation (Boonruab *et al.*, 2020; Ioannou *et al.*, 2023). Commercially, Yadum is available as black solid lumps sold in Thai herbal drugstores. It is considered expensive, with a market price ranging from 800 to 1,000 baht (approximately 30 USD) per kilogram. Currently, Yadum is not produced domestically in Thailand and must be imported from countries such as China or India. Promoting domestic production of dried *A. vera* latex could reduce dependency on imports and increase the economic value of the currently underutilized parts of *A. vera* cultivation.

Even though aloin and aloe-emodin exhibit several medicinal properties, the consumption of high doses of these anthraquinones can be harmful to the gastrointestinal tract. Several studies have reported that excessive intake of anthraquinones may lead to chronic inflammation of the large intestine (Jangral *et al.*, 2022; Ioannou *et al.*, 2023). Therefore, aloe gel products widely used in food and beverages should contain only appropriate and safe

levels of anthraquinones. The levels of aloin and aloe-emodin in aloe latex vary depending on the geographical location and climate where the plants are cultivated (Kumar *et al.*, 2017). *Aloe vera* grown in colder climates has been shown to contain higher levels of these compounds compared to plants grown in warmer regions. However, there is currently no evidence-based report on the levels of aloin and aloe-emodin in latex and gel obtained from *A. vera* leaves cultivated using different methods. Moreover, the anthraquinone content in commercial dry latex remains unclear, and limited information is available regarding the levels of aloin and aloe-emodin in fresh latex and gel from *A. vera* cultivated in Thailand.

In 2019, the total area cultivated with *A. vera* in Thailand was approximately 194 hectares, with a production of around 97,692 tons (Kitprathaung and Pianjing, 2023). The harvested leaves are primarily utilized by the culinary, pharmaceutical, and cosmetic industries. However, the peel and latex from these harvested leaves remain unused and are typically discarded as waste (Kitprathaung and Pianjing, 2023). Despite their current underutilization, the peels of *A. vera* contain numerous bioactive compounds, notably anthraquinones such as aloin and aloe-emodin (Cordiano *et al.*, 2025). These compounds have demonstrated antioxidant, anti-inflammatory, antibacterial, and antifungal activities, highlighting the potential of aloe peel as a valuable raw material (Cordiano *et al.*, 2025). Utilizing these discarded peels could not only reduce agricultural waste but also enhance the economic sustainability of *A. vera* cultivation by facilitating the development of novel health products and biopharmaceutical applications. One particularly promising area of research is the exploration of the antifungal potential of *A. vera*-derived compounds, specifically against *Candida albicans*, an opportunistic fungal pathogen responsible for conditions such as oral thrush, vaginal candidiasis, and systemic infections (Nabila and Putra, 2020). The increasing prevalence of antifungal resistance, along with adverse side effects associated with conventional antifungal medications, has further intensified interest in natural alternative treatments (Nabila and Putra, 2020).

Therefore, the objectives of this study were to determine the levels of aloin and aloe-emodin in dry and fresh latex of *A. vera* leaves, and to compare these levels across samples cultivated in different geographical areas and under varying methods. Additionally, anthraquinones were extracted from

discarded *A. vera* peels obtained during food processing, and the resulting crude extracts were analyzed to determine their aloin and aloe-emodin contents. Finally, the antifungal activity of these crude extracts was evaluated, specifically targeting their effectiveness against *C. albicans*.

Materials and Methods

Chemicals and Reagents

Phosphate buffer saline (PBS), acetonitrile, aloin, and aloe-emodin were purchased from Sigma Aldrich, Germany. Nitric acid (HNO_3) was purchased from Merk (KgaA, Darmstadt, Germany).

A. vera Latex Collection

The two commercial dry latex samples of *A. vera* referred to as 'Yadum', were chosen to serve as the anthraquinone reference source utilized in Thai pharmaceuticals as shown in Figure 1. They were the black solid lumps imported from China. The Yadum samples in this study were purchased from two distinct herbal drug stores in Chinatown of Bangkok and Samut Songkhram Province, Thailand, twice following importation of the dry latex. Yadum 1 was purchased from the first herbal drugstore, called 'Chao Grom Pur', located in Chinatown Bangkok, and Yadum 2 was purchased from the second herbal drugstore, called 'Jed Dao herbal drug store', located in Samut Songkhram Province.

Fresh latex samples of *A. vera* were collected from two farms. The first farm is located in Prachuap Khiri Khan Province. This farm cultivates the *A. vera* on the sandy loam of corrugated land as

shown in Figure 2. The farmer obtained water to irrigate the *A. vera* plants from nearby little waterways. The plants were watered in the morning every three days by using sprinkle technique. Fresh latex samples collected from this farm are referred to as fresh latex Prachuap or FLP. The second farm is located in Ratchaburi Province. This farm used the ridge planting method to grow *A. vera*, as illustrated in Figure 3. There were numerous soil ridges with small streams surrounding them. The plants were cultivated on the ridges and the farmer extracted the water from tiny waterways. The fresh latex samples derived from this farm were the fresh latex Ratchaburi or FLR.

Fresh yellow latex was collected by draining the exudate from the epidermal cells of *A. vera*



Figure 1. Commercial dry aloe latex extract or 'Yadum'



Figure 2. *A. vera* cultivated in a corrugated area at Prachuap Khiri Khan Province, Thailand



Figure 3. *A. vera* cultivated in a corrugated area at Prachuap Khiri Khan Province, Thailand

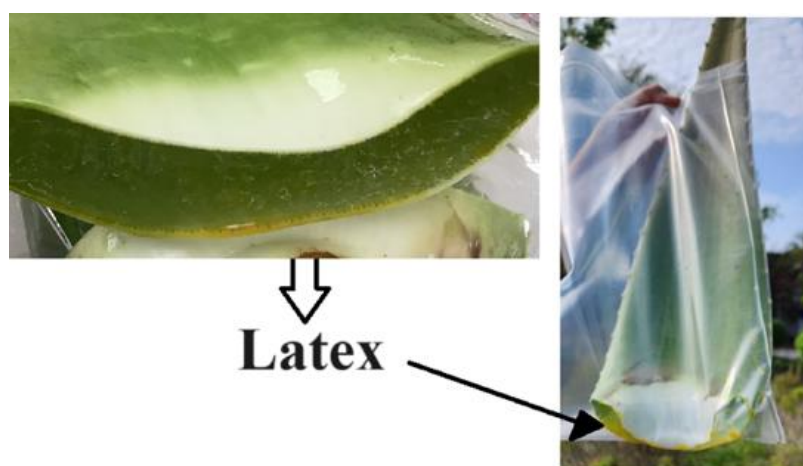


Figure 4. Latex from *A. vera* leaves

leaves, as illustrated in Figure 4. For each sample, five mature outer leaves were cut at the base and allowed to drain for 30-40 min. Three replicates of five mature leaves were collected, for the latex samples, and then, the samples were composited. The collected latex was stored in plastic bags. Leaf sampling was conducted twice in 2022—once in the dry season (April) and once in the wet season (August). Leaves were randomly selected from plants that were at least one year old. Upon exposure to air, the latex darkened due to oxidation. The latex samples were immediately stored in ice boxes at 4°C and subsequently used for anthraquinone extraction.

***A. vera* Flesh Gel Collection**

After collecting the latex from *A. vera*, the flesh gel samples were collected further.

The peels of *A. vera* leaves were removed to obtain the gel flesh samples. The gel samples from five leaves were cut into small pieces approximately 2 cm long and then stored in the icebox. The gel samples derived from Prachuap Khiri Kann Province were GP and the gel samples derived from Ratchaburi Province were GR.

***A. vera* peels collection**

The discarded *A. vera* peels were collected from the Ratchaburi Province as shown in Figure 5. The discarded aloe peels were kept in plastic bags, and they were brought to the laboratory of the College of Allied Health Science, Suan Sunandha Rajabhat University, Thailand. The aloe peels were kept in a refrigerator at 4°C until analysis.



Figure 5. Collecting discarded *A. vera* peels

Anthraquinone Extract

The PBS powder was dissolved in 1 L of deionized water, and the pH was adjusted to 3 using HNO_3 . The extraction of aloin and aloe-emodin from commercial dry latex, fresh latex, and gel samples was performed using PBS at pH 3, following the method described by Sánchez-Machado *et al.* (2017). Fresh latex samples were first dried at room temperature (25°C) for 24 h, and then further dried in a hot air oven (Memmert UN55, Germany) at 70°C. Approximately 5 g. of each dried fresh latex sample was dissolved in 5 mL of PBS (pH 3). Similarly, 5 g. of each commercial latex sample (Yadum 1 and Yadum 2) was dissolved in PBS (pH 3). All latex-PBS mixtures were sonicated for 10 mins and filtered using Whatman No. 4 filter paper. Aloe gel samples were blended using a mixing machine and dried in a hot air oven at 70°C until constant weight was achieved. Approximately 10 g. of the dried aloe gel was dissolved in PBS (pH 3), sonicated for 10 mins, and filtered using Whatman No. 4 filter paper.

Anthraquinones from aloe peels (APE) were extracted following the method of Tan *et al.* (2013). Fresh aloe peels (1 kg) were cut into small pieces and soaked in 1.5 kg. of PBS (pH 3) for 24 h. After soaking, the PBS solution turned dark brown color. The mixture was then filtered through Whatman No. 4 filter paper. The filtrate was dried at 70°C to remove water, yielding a dark brown colloidal aloe extract. This extract was stored at 4°C until analysis.

Determination of Aloin and Aloe-Emodin

Quantitative analysis of aloin and aloe-emodin was performed using high-performance liquid

chromatography (HPLC) (Agilent Technologies, 1260 infinity), following the protocols described by Kline *et al.* (2017) and Sánchez-Machado *et al.* (2017). Data acquisition and analysis were conducted using Agilent software. Chromatographic separation was carried out isocratically at 35°C using an ACE Generix 5 C18 column (4.6×250 mm, 5 μm particle size). The mobile phase consisted of acetonitrile and water (30:70, v/v), delivered at a flow rate of 1 mL/min. The injection volume was 10 μL , and detection was performed at a wavelength of 254 nm. Method validation included the evaluation of linearity, limit of detection (LOD), and limit of quantification (LOQ). The LOD and LOQ were calculated based on the standard deviation of the response (δ) and the slope of the calibration curve (S), using the following equations: $\text{LOD} = 3.3 \times (\delta/S)$ and $\text{LOQ} = 10 \times (\delta/S)$, where δ represents the standard deviation of the Y-intercept of the calibration curve.

Yeast Extraction, Media Culture and Preparation

The yeast strain used in this study was *C. albicans* (TISTR 5815). A non-ionic, water-soluble crude extract of *A. vera* peels was prepared using deionized water (DI) at a concentration of 1 mg/mL. Yeast cultures were maintained on Yeast Malt Extract Broth (YMB) and Yeast Malt Extract Agar (YMA). Sterile YMB culture dishes were prepared in duplicate by two individuals (2×YMB) to ensure reproducibility and aseptic handling. Pure cultures of *C. albicans* stored at 4°C were transferred into 10 mL tubes containing sterile YMB and incubated at 30°C for 24 h. This subculturing

process was repeated three consecutive times to ensure active and stable growth. After the third incubation, the yeast cells were enumerated using the spread plate method on YMA, and the initial cell density was determined to be approximately 7-8 Log CFU/mL (10^7 - 10^8 CFU/mL).

To obtain a standardized working concentration, the yeast cells were suspended in sterile saline (0.85% NaCl), and the turbidity of the suspension was adjusted spectrophotometrically to match the 0.5 McFarland standard. This standard corresponds to an optical density (OD) of approximately 0.12-0.15 at 530 nm, which is equivalent to 10^7 - 10^8 CFU/mL. The final concentration was further verified by performing serial dilutions and spread plating 100 μ L of diluted samples onto YMA plates, followed by incubation at 30°C for 24-48 h. Colony-forming units (CFUs) were counted to confirm that the yeast suspension was within the desired concentration range before its use in antifungal activity testing.

Evaluation of Aloe Extract's Inhibitory Effect on *C. albicans* using the Agar Well Diffusion Method

The agar well diffusion method was used to evaluate the antifungal activity of crude *A. vera* extract against *C. albicans*, following protocols outlined by the Clinical and Laboratory Standards Institute (CLSI, 2013) and Davidson *et al.* (2005). Crude extract concentrations of 1, 0.5, 0.25, and 0.125 mg/mL were tested. Molten Yeast Malt Agar was poured into 40 mL Petri dishes and allowed to solidify. An 18-h *C. albicans* culture suspension, with an initial concentration of approximately 7-8 Log CFU/mL, was uniformly spread across the agar surface using a sterile cotton swab. After allowing the inoculum to absorb for 3-5 mins, 6 mm diameter wells were made in the agar using a sterile cork borer (No. 2). Each well was filled with 100 μ L of *A. vera* extract at the designated concentrations, while DI water served as the negative control. The plates were incubated at 30°C for 24 h. Antifungal activity was evaluated by observing the formation of clear zones (inhibition zones) around the wells, and the diameters of these zones were measured in millimeters.

Assessment of Aloe Peels Crude Extract's Inhibitory Effect on *C. albicans*

This study employed the broth dilution method to assess the inhibitory effect of *A. vera* peel crude extract on *C. albicans*. A modified broth dilution protocol, adapted from Tantala *et al.* (2012), was used to determine the minimum inhibitory concentration (MIC) and minimum fungicidal concentration (MFC) of the extract. An 18-h culture of *C. albicans*, as described in Section 2.2, was prepared at an initial concentration of approximately 4-5 Log CFU/mL in 5 mL of 2 $\times$ YMB medium. To this, 5 mL of either the crude extract solution (final concentration: 0.5 mg/mL) or DI water (control) was added. The mixtures were then incubated at 30°C for 24 h. Microbial growth was evaluated using the spread plate method on YMA medium, followed by incubation at 30°C for an additional 24 h. The MIC was defined as the lowest concentration of crude extract that inhibited visible fungal growth after 24 h. The MFC was defined as the concentration that reduced the fungal count by $\geq 99.9\%$, equivalent to a reduction of at least 3 log cycles from the initial CFU/mL count, in accordance with the definition provided by Tantala *et al.* (2012). Additionally, inhibition zone diameters from the agar diffusion assay were measured using an automated zone reader (SCAN 4000®, Interscience, France).

Statistical Analysis

Differences in aloin and aloe-emodin levels among latex, gel, and crude extracts from aloe peels were analyzed using the Mann-Whitney U test. The Kruskal-Wallis test was applied to assess differences in aloin and aloe-emodin levels in latex samples obtained from different sources.

Results and Discussion

Qualitative Analysis of Aloin and Aloe-Emodin

The chromatogram of aloin and aloe-emodin standards analyzed by HPLC at 254 nm are shown in Figure 6. Method validation, LOD, and LOQ results are shown in Table 1.

Table 1. Method validation of aloin and aloe-emodin

Substances	Ranges (μ g/mL)	Equation	r^2	LOD mg/g	LOQ mg/g
Aloin	1-80	$Y=4.63x - 0.677$	>0.99	0.08	0.26
Aloe-emodin	1-80	$Y=44.943x - 56.371$	>0.99	0.06	0.19



Figure 6. Chromatogram of aloin and aloe-emodin

Table 2. Aloin and aloe-emodin content in the latex and gel of *A. vera*

Sample	Aloin (mg/g)	Aloe-emodin (mg/g)
Yadum1	20.53 ^a (12.18–28.88)	2.25 ^a (1.03–3.47)
Yadum 2	30.79 ^a (31.67–29.85)	4.82 ^a (3.78–5.85)
FLP	16.16 ^a (15.91–16.41)	2.91 ^a (2.61–3.21)
FLR	18.33 ^a (17.86–18.80)	3.45 ^a (1.26–5.64)
GP	3.32 ^b (2.97–3.66)	0.20 ^b (0.18–0.23)
GR	0.44 ^b (0.25–0.63)	0.18 ^b (0.17–0.19)
APE	3.35 ^b (2.98–3.67)	0.23 ^b (0.19–0.28)

Note: Data shown as average and the numbers in brackets are minimum value – maximum value; N = 2; In the same column, the means followed by the same letter are not significantly different according to the Mann-Whitney test at $p < 0.05$

Table 3. Comparison of aloin and aloe-emodin contents in latex and aloe gel samples from this study and previous reports

Sources of data	Aloin (mg/g)			Aloe-emodin (mg/g)		
	Dry latex	Fresh latex	Aloe gel	Dry latex	Fresh latex	Aloe gel
Sánchez-Machado ¹ <i>et al.</i> (2017)	291.16	247.73	13.41	-	-	-
Kumar <i>et al.</i> (2017)	-	-	0.45	-	-	0.29
Sadiq <i>et al.</i> (2022)	-	-	6.15	-	-	0.069
Nakiguli <i>et al.</i> (2022)	237.97	-	0.10	-	-	-
This study	30.79	18.33	3.32	4.82	3.45	0.20

Aloin and Aloe-Emodin Content in Latex, Aloe Peel Crude Extract, and *A. vera* Gel

Our results showed that five fresh *A. vera* leaves yielded approximately 3–5 g. of latex. As presented in Table 2, the concentrations of aloin and aloe-emodin in fresh and commercially dried latex samples ranged from 16.16 mg/g to 30.79 mg/g and 2.25 mg/g to 3.45 mg/g, respectively. In APE, aloin levels were between 2.98 and 3.67 mg/g, while aloe-emodin levels ranged from 0.19 mg/g to 0.28 mg/g. There was no significant difference in aloin content between fresh and commercial dry latex samples. Additionally, the concentration of aloin was consistently higher than that of aloe-emodin in all latex samples.

In the aloe gel samples, aloin and aloe-emodin levels ranged from 0.44 mg/g to 3.32 mg/g and 0.18 mg/g to 0.20 mg/g, respectively, as shown in

Table 2. According to the Kruskal-Wallis test, there were no statistically significant differences in the levels of aloin and aloe-emodin in aloe gel samples collected from different cultivation methods or geographic areas. Similarly, when comparing samples collected during the dry and wet seasons, no significant differences were observed in the levels of these compounds.

However, based on the Mann-Whitney U test, statistically significant differences ($p < 0.05$) were found between the levels of aloin and aloe-emodin in latex, aloe gel, and aloe peel crude extract. The anthraquinones aloin and aloe-emodin were higher in aloe latex than in aloe gel and the crude peel extract.

When comparing the levels of aloin and aloe-emodin in latex and aloe gel samples with those reported in previous studies (Table 3), it was found

Table 4. Effectiveness of aloe peel extract on *C. albicans* inhibition

Testing substance	Fungal count (log CFU/ML)	
	0 h	24 h
Control	4.63	8.12
Aloe peel extract (0.5 mg/mL)	4.63	8.24

Table 5. Inhibition zone diameters of *C. albicans* treated with aloe peel crude extract

Crude extract concentration (mg/mL)	Inhibition diameter (mm)
Control (DI water with 5% of Tween20)	6.00±0.00
10	11.35±0.49
15	13.00±0.00
20	13.70±0.28
25	14.40±0.71
30	15.55±0.49

Note: Inhibition diameters are expressed as mean ± standard deviation (SD). The central well diameter without inhibition is 6.00 mm, which corresponding to a no- inhibition zone.

that the aloin content in both dry and fresh latex was lower than the levels reported by Sánchez-Machado *et al.* (2017) and Nakiguli *et al.* (2022). Similarly, the aloin concentration in the aloe gel from this study was lower than that reported by Sánchez-Machado *et al.* (2017) and Sadiq *et al.* (2022). However, the aloin content observed in this study was higher than that reported by Kumar *et al.* (2017) and Nakiguli *et al.* (2022) in their respective studies. The amount of aloe-emodin detected in the aloe gel in this study was comparable to the level reported by Kumar *et al.* (2017), as shown in Table 3.

Evaluation of the Inhibitory Effect of Aloe Peel Crude Extract on *C. albicans* using the Agar Well Diffusion Method

The agar well diffusion assay was performed using aloe peel crude extract at aloin-equivalent concentrations of 1, 0.5, 0.25, and 0.125 mg/mL. The results showed no visible inhibition zones at any of the tested concentrations, indicating that the extract, at these levels, did not exhibit antifungal activity against *C. albicans* under the assay conditions.

Evaluation of the Inhibitory Efficiency of Aloe Peel Crude Extract on *C. albicans*

The antifungal activity test of *A. vera* peel crude extract at a concentration of 0.5 mg/mL revealed that the extract was ineffective in inhibiting the growth of *C. albicans* compared to the control group, as shown in Table 4.

The initial results indicated that the selected concentration of aloe peel crude extract (0.5 mg/mL) did not inhibit the growth of *C. albicans*. Therefore, to enhance the solubility and bioavailability of the extract, the study increased

**Figure 7. Inhibition zones formed by aloe peel extract against *Candida albicans* at higher concentrations**

the extract concentrations and incorporated 5% Tween 20 in deionized water as a solubilizing agent. The revised concentrations 10, 15, 20, 25, and 30 mg/mL were tested for antifungal activity using the agar well diffusion method. The results revealed that increasing the concentration of the aloe peel extract, along with the addition of 5% Tween 20, resulted in clear inhibitory effects against *C. albicans*, as illustrated in Figure 7. A direct correlation was observed between extract concentration and inhibition zone diameter: the higher the concentration, the larger the inhibition zone. Among the tested concentrations, the extract at 30 mg/mL exhibited the most pronounced antifungal effect, producing an inhibition zone of 15.55±0.49 mm, as shown in Table 5.

Table 6. Inhibitory effect of aloe peel extract on *C. albicans* using the broth dilution method

Concentrations (mg/mL)	Fungal count (Log CFU/mL)	
	0 h	24 h
DI water	4.68	7.83
DI water mixed with 5% Tween 20	4.68	8.07
5	4.68	7.43
10	4.68	5.33
15	4.68	ND

Note: ND indicates "not detected," meaning no fungal growth was observed after incubation.

Evaluation of the Effectiveness of Aloe Peel Crude Extract in the Inhibition of *C. albicans* Using the Broth Dilution Method

The antifungal activity of aloe peel crude extract against *C. albicans* was evaluated using the broth dilution method. The extract was tested at concentrations of 5, 10, and 15 mg/mL. The results demonstrated a concentration-dependent inhibition of *C. albicans*, with the number of detectable fungal cells decreasing as the extract concentration increased. After 24 h of incubation, complete inhibition of *C. albicans* was observed at 15 mg/mL, with no fungal growth detected. Based on these results, the MIC and MFC of the aloe peel extract against *C. albicans* were both determined to be 15 mg/mL, as summarized in Table 6.

Discussion

A. vera latex is the exudate that drains from the vascular bundles located beneath the thick rind of aloe leaves. This latex, also referred to as aloe sap, has a distinctly bitter taste due to the presence of anthraquinones (Guo and Mei, 2016). The primary source of anthraquinones in *A. vera* is the latex obtained from freshly cut leaves. As such, the levels of aloin and aloe-emodin found in the latex samples in this study were higher than those found in the aloe gel. In this study, latex collection from five *A. vera* leaves yielded only 3-5 g. of latex, indicating that latex production in this species is relatively low. In Thailand, *A. vera* is primarily cultivated for its gel, which is produced in higher quantities and is widely used in the food, cosmetic, and pharmaceutical industries. In contrast, latex production is not prioritized, as it is not only economically less attractive but also causes skin irritation for farmers during harvest. An alternative species, *A. ferox*, is widely cultivated in South Africa for its latex, which is harvested for pharmaceutical purposes (Chen *et al.*, 2012). *A. ferox* differs morphologically from *A. vera*; its leaves are covered with prominent thorns, and the inner gel content is lower than that of *A. vera*

(Chen *et al.*, 2012). However, *A. ferox* produces a higher volume of latex per leaf, offering an advantage for anthraquinone extraction (Kitprathaung and Pianjing, 2023). According to Nalimu *et al.* (2021), the yield and quality of aloe latex depend on several factors, including the climatic conditions of the growing area, the plant part used, the age of the plant, and the extraction method. In this study, latex was collected from one-year-old *A. vera* leaves, which may contain lower levels of anthraquinones compared to more mature leaves. Future studies should investigate latex composition in *A. vera* leaves of different ages to identify the optimal harvesting time for maximizing anthraquinone yield. Importantly, aloe latex that is typically discarded during gel harvesting could be collected and repurposed as a medicinal ingredient. This approach would increase the overall value of *A. vera* cultivation and support sustainable agricultural practices.

The amounts of aloin and aloe-emodin found in *A. vera* fresh latex in this study were comparable to those detected in commercial dry latex, suggesting that fresh latex collected from plantation areas in Thailand has potential for use in Thai traditional medicine. However, there are currently no legal regulations in Thailand specifying the required concentrations of aloin and aloe-emodin in dry latex, or Yadum. As a result, it remains unclear whether the levels of aloin and aloe-emodin detected in Yadum products are appropriate for therapeutic use in humans. The Thai Herbal Pharmacopoeia recommends using of 12 g. of dry aloe latex in the formulation of traditional Thai laxative medicines (reference not cited due to its availability only in the Thai language). This study is the first to report the actual concentrations of aloin and aloe-emodin in commercially available Yadum used for such preparations. It is important to note, however, that the commercial dry latex samples analyzed in this study were purchased from herbal drugstores, and the storage duration and conditions prior to purchase were unknown. Improper storage conditions could have led to the degradation of bioactive compounds, potentially

contributing to the relatively low levels of aloin and aloe-emodin observed in this study when compared to values reported in previous literature (as shown in Table 3). According to Ioannou *et al.* (2023), aloin A and B degrade over time under non-acidic storage conditions. The dry latex samples in this study were stored at room temperature and not under acidic conditions, which may have accelerated the degradation of these anthraquinones. Therefore, maintaining the stability and therapeutic concentrations of active ingredients in commercial dry latex may be challenging without proper storage and quality control measures.

The results of this study indicated that there were no significant differences in the levels of aloin and aloe-emodin in *A. vera* latex and gel collected from different cultivation areas, using different planting methods, and harvested at different times. The cultivation areas included in this study are located in the western region of Thailand, where the tropical climate and rainfall patterns are relatively uniform. These consistent environmental conditions may explain the similar concentrations of active compounds, suggesting that cultivation under similar climates may not significantly influence anthraquinone content in *A. vera*. However, previous studies have reported that harvesting time can influence aloin concentrations. Ioannou *et al.* (2023) and Beppu *et al.* (2004) found significant variations in aloin levels depending on the season of harvest. Specifically, Ioannou *et al.* (2023) reported that aloe leaves harvested in the summer contained higher aloin concentrations compared to those collected in winter. Although the *A. vera* plants in this study were grown using different cultivation methods, no significant differences in aloin concentrations were observed in either the latex or the gel. According to Ioannou *et al.* (2023), *A. vera* grown under stress conditions, such as high salinity, limited water supply, or intense sunlight, can exhibit lower aloin concentrations. Supporting this, Hazrati *et al.* (2017) also noted that environmental stressors affect the synthesis of bioactive compounds in plants. Stressed *A. vera* plants often develop reddish-brown leaves and contain less gel. In contrast, the aloe plants examined in this study showed healthy green leaves with abundant gel content. Both farms involved in the study had adequate irrigation and watered the plants regularly. These conditions likely prevented environmental stress and allowed for consistent production of high-quality leaves, resulting in similar anthraquinone levels regardless of the cultivation method.

The presence of anthraquinones in aloe gel, as observed in this study, also raises important considerations for food and cosmetic applications.

Although anthraquinones such as aloin and aloe-emodin possess recognized medicinal properties, excessive exposure, particularly through contaminated food or skincare products, may be harmful. High intake of anthraquinones has been associated with gastrointestinal irritation and diarrhoea (Nalimu *et al.*, 2021). Therefore, it is recommended that aloe gel be thoroughly washed multiple times before consumption or processing to minimize the risk of residual anthraquinone exposure.

The discarded aloe peels used in this study are considered agricultural waste, typically removed during the extraction of aloe gel. However, the findings revealed that these discarded peels contain significant amounts of aloin and aloe-emodin, indicating their potential as a valuable source of bioactive compounds for medicinal use. The inhibitory effect on *C. albicans* observed in this study suggests that aloe peels retain active constituents, particularly anthraquinones like aloin and aloe-emodin, which possess antimicrobial properties. These results are consistent with the findings of Danish *et al.* (2020), who reported that extracts from the whole leaves and roots of *A. vera* demonstrated antifungal activity against *C. albicans*. Similarly, Shireen *et al.* (2015) identified anthraquinones as the primary class of compounds responsible for the antifungal activity of *A. vera*. Aloe leaf extracts have been widely reported to exhibit pharmaceutical effects against a range of microbial pathogens. Given the antifungal activity demonstrated in this study, aloe peel extracts may have practical applications in oral healthcare products. Thaweboon and Thaweboon (2020) showed that *A. vera*-based toothpaste exhibited antifungal activity against *C. albicans* isolated from the human oral cavity. Therefore, extracts derived from discarded aloe peels may serve as a promising, sustainable alternative for incorporation into personal care and healthcare products. Regarding the antimicrobial mechanism of *A. vera* extracts, it is speculated that active constituents such as anthraquinones exert their effects by disrupting the fungal cell wall or altering cell membrane permeability. These disruptions can lead to the leakage of cytoplasmic contents and ultimately result in cell death (Salim *et al.*, 2019). This mechanism supports the observed antifungal activity and highlights the potential of aloe peel as a natural effective antifungal agent.

Conclusions

The results of this study revealed that latex extracted from *A. vera* leaves cultivated in Thailand can be

utilized as a medicinal ingredient with laxative properties. This is the first report to quantify the levels of aloin and aloe-emodin in both fresh and dried aloe latex collected in Thailand. The concentrations of aloin and aloe-emodin in fresh latex were comparable to those in dry latex, suggesting that fresh *A. vera* latex could be developed for use in Thai traditional medicine. In contrast, the levels of aloin and aloe-emodin in aloe gel were relatively low compared to those found in latex. Additionally, discarded aloe peels showed potential as a source of bioactive compounds capable of inhibiting *C. albicans*. Crude extracts from the peels successfully inhibited the growth of *C. albicans* in an in vitro study.

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