Research Article

Effect of Piper betle and Brucea javanica on the Differential Expression of Hyphal Wall Protein (HWP1) in Non-Candida albicans Candida (NCAC) Species

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The study aimed to identify the HWP1 gene in non-Candida albicans Candida species and the differential expression of HWP1 following treatment with Piper betle and Brucea javanica aqueous extracts. All candidal suspensions were standardized to $1 \times 10^6$ cells/mL. The suspension was incubated overnight at 37°C (C. parapsilosis, 35°C). Candidal cells were treated with each respective extract at 1, 3, and 6 mg/mL for 24 h. The total RNA was extracted and reverse transcription-polymerase chain reaction was carried out with a specific primer of HWP1. HWP1 mRNAs were only detected in C. albicans, C. parapsilosis, and C. tropicalis. Exposing the cells to the aqueous extracts has affected the expression of HWP1 transcripts. C. albicans, C. parapsilosis, and C. tropicalis have demonstrated different intensity of mRNA. Compared to P. betle, B. javanica demonstrated a higher suppression on the transcript levels of HWP1 in all samples. HWP1 was not detected in C. albicans following the treatment of B. javanica at 1 mg/mL. In contrast, C. parapsilosis and C. tropicalis were shown to have HWP1 regulation. However, the expression levels were reduced upon the addition of higher concentration of B. javanica extract. P. betle and B. javanica have potential to be developed as oral health product.

1. Introduction

Candida is a genus of yeast-like fungi that are commonly part of the normal flora of the mouth, skin, intestinal tract, and vagina. Areas of recovery of Candida species in the oral cavity include the dentition, tongue, cheeks, and palatal mucosa, as well as from restorative materials and prostheses [1]. Morphologically, the size of Candida cell is about 4–6 μm. Approximately, around 196–200 species of Candida have been identified so far [2]. Oral candidiasis (oral thrush) is a common candidal infection in human oral cavity. Among the several Candida species, Candida albicans is most frequently isolated from patients with candidiasis. C. albicans has been reported to have the ability to grow as yeast, hyphae, and pseudohyphae [3]. However, recently there are reports on the prevalence of non-Candida albicans Candida (NCAC) species such as Candida dubliniensis, Candida glabrata, Candida krusei, Candida lusitaniae, Candida parapsilosis, and Candida tropicalis being associated with oral candidiasis [4, 5].

The opportunistic characteristic of Candida species allows the transition from harmless to a pathogenic microorganism and is responsible for a wide range of systemic and superficial infections in the immunocompromised hosts [6]. A number of virulence factors such as adhesion, hydrolytic enzyme production for example, proteinases and phospholipases, hyphal formation, and phenotypic switching may be involved to establish an infective process.

Candidal cell wall is a dynamic structure and represents the prime site to interact with oral epithelial cells. HWP1 is the first cell surface protein known to be required for C. albicans biofilm formation in vivo [7]. The HWP1 functions as adhesins in the cell wall, promoting the attachment of candidal cells to host mucosal surface. Although it has been described as hypha-specific adhesins [8], recent studies have
shown that HWP1 transcript may arise from pseudohyphal growth forms [9].

Malaysia is well known for its plant biodiversity. Some of them are utilized for medicinal purposes. Brueca javanica (L.) Merr is a member of the family Simaroubaceae. The seeds of this plant have been used in traditional medicine of Indonesia and China [10, 11]. It has also been reported to be a sapogenin of the Indonesian and antimicrobial properties [14, 15]. It is also popular as an antiseptic and is commonly applied on wounds and lesions for healing effects [16,17]. Due to its strong pungent aromatic flavour, it is widely used as a postmeal mouth freshener and masticatory by the Asian people. This particular property has paved way for further experimental studies on P. betle [18].

In the present study, we focused on the association of HWP1 in the NCAC species. HWP1 of C. albicans has been extensively studied, reflecting the growing concern over its role in various stages of infections. Information on the expression levels of HWP1 transcripts that encode adhesins amongst the NCAC species, however, is scarce. The hyphal formation between Candida species has the propensity to express distinctive pattern of HWP1. Therefore, this study aimed to identify the expression of HWP1 mRNA transcript in NCAC species and to examine the regulation of HWP1 following treatment with B. javanica and P. betle aqueous extracts.

2. Materials and Methods

2.1. Preparation of Crude Aqueous Extract. Fresh leaves of Piper betle and the seeds of Brueca javanica were collected from local areas in Brickfields and Sekinchan, Malaysia. Crude aqueous extracts of the plants were prepared [19]. Each specimens was weighted at 100 g, followed by rinsing under running tap water, and dried for 2 days at 60°C. The respective dried specimen was homogenized in distilled water at a ratio of specimen to water of 1:10. The homogenate was heated at high temperature and concentrated to 1/3 of the original volume. The decocition was filtered through a Whatman No. 1 filter paper. The filtrate was freeze-dried (EYELA FDU-120, Tokyo) overnight, and the fine powder obtained was kept in a sterile Falcon tube and stored at 4°C.

2.2. Preparation of Candidal Suspension. Seven candidal strains, Candida albicans (ATCC 14053), Candida dubliniensis (ATCC MYA-2975), Candida glabrata (ATCC 90030), Candida krusei (ATCC 14423), Candida lusitaniae (ATCC 64125), Candida parapsilosis (ATCC 22019), and Candida tropicalis (ATCC 13803), were purchased from the American Type Culture Collection (ATCC), USA. The candidal cells were revived in 10 mL Yeast Peptone Dextrose (YPD) broth and the turbidity of the suspension was adjusted spectrophotometrically to an optical density (OD550 nm) of 0.144 which is equivalent to 1 × 10⁶ cells/mL. This standard suspension was used throughout the experiment.

2.3. Treatments of Piper betle and Brueca javanica on Candida Species. The standardised suspension (10⁶ cells/mL) of each strain was incubated overnight at 37°C (C. parapsilosis, 35°C) to allow the propagation of cells. The cultures were acclimatized for 1h, followed by the addition of sub-MICS of 1, 3, and 6 mg/mL. The MICs of Piper betle and B. javanica were determined between 25 to 12.5 mg/mL [19]. After 24 h, 3 mL of each respective culture was centrifuged at 8,000 × g (4°C) for 5 min and the supernatant was discarded. The treated pellets were washed twice with phosphate-buffered saline (PBS, pH 7.2), and the total RNA extraction was performed. For the untreated samples, total RNA was isolated from the non-treated pellets.

2.4. Oligonucleotide Sequences. A pair of primer specifically designed for HWP1 mRNA was purchased from the 1st BASE Laboratories, Malaysia. The primer was used in reverse transcription-polymerase chain reaction (RT-PCR) to amplify the sequences that encode for HWP1 in Candida species. ACT1 primer was used as a positive control to detect Candida species carrying HWP1 gene.

2.5. Optimization of Primers. Annealing temperature is a key factor in performing PCR amplification for reaction specificity. The optimization was carried out with the Mastercycler gradient. A gradient of 60°C ± 5°C was programmed and the temperature distribution in the individual columns of the block was set at 55°C, 57°C, 59°C, 61°C, 63°C, and 65°C.

2.6. Total RNA Extraction. Freshly prepared candidal suspensions were inoculated into 10 mL YPD broth and incubated overnight at 37°C in a rotary shaking incubator. 3 mL of the respective cell suspension was centrifuged at 2,000 × g for 10 min in a 4°C refrigerated centrifuge and the supernatant was discarded. The pellet formed was washed with sterile PBS, pH 7.2. Following that, total RNA was extracted using an easy-RED BYF Total RNA Extraction kit (Intron Biotechnology Inc.) according the manufacturer’s instruction.

Next, 250μL of prelysis buffer was added and re-suspended thoroughly. A 750 μL of easy-RED solution was added, vigorously mixed for 15 s, and left at room temperature for 5 min. Following the addition of 200 μL of chloroform, the samples were vigorously mixed for 15 s and left at room temperature for 5 min.

The samples were centrifuged at 8,000 × g (4°C) for 15 min, and the colourless aqueous phase formed was transferred to a new microcentrifuge tube. An equal volume of isopropanol (2-propanol) was added, mixed by inverting the tube for 6-7 times, and left at room temperature for 10 min. The suspension was recentrifuged at 8,000 × g (4°C) for 10 min, and the supernatant was discarded without disturbing the pellet.

One millilitre of 70% ethanol was added and mixed by inverting the tube several times. The mixture was centrifuged at 8,000 × g (4°C) for 5 min. The supernatant was discarded and the RNA pellet was left to dry. The pellet was dissolved in 25μL of RNase-free water and stored at −80°C.
2.7. RNA Quantification. The RNA samples were analyzed for its integrity using the Agilent 2100 Bioanalyzer and all samples were considered to have high quality RNA by referring to the RIN number [22].

2.8. Reverse Transcription-Polymerase Chain Reaction. Fifty ng/mL of the RNA template and 1 mL of each primer were mixed in 10 μL of Prime RT-PCR Premix 2X (GENET BIO) which contained HS Prime Taq DNA polymerase, Prime MMLV reverse transcriptase, reaction buffer, 0.1 mM dNTPs mixture, RNase inhibitor, protein stabilizer, and enhancers for cDNA synthesis. RNase-free water was added up to a total reaction volume of 20 μL.

Reverse transcription was carried out at 42°C for 30 min to synthesis the cDNA, followed by denaturation at 94°C for 10 min to deactivate the reverse transcriptase and activate the HS Prime Taq DNA polymerase. The samples were subjected to 30 cycles of denaturation (94°C), annealing (56°C to 64°C), and extension (72°C), each for 30 s. Lastly, the final extension was at 72°C for 5 min.

The amplicon of 6 μL was separated by electrophoresis in 1.5% (w/v) of agarose gel and stained with ethidium bromide. A Tris-borate-EDTA (TBE) was used as a running buffer and 100 bp DNA ladder (BIO-RAD) was used as a molecular weight marker. The expression of the gene was visualized by ultraviolet (UV) illumination (Alphaimager 2200, Alpha Innotech).

3. Results

The expression of HWP1 transcript was investigated in seven Candida species cultured in YPD broth for 24 h. mRNAs from all candidal spp. were loaded accordingly and results of gel electrophoresis after RT-PCR are shown in Figure 1. While ACT1 was used as the positive control, it was observed that HWP1 mRNAs were only expressed in C. albicans, C. parapsilosis, and C. tropicalis after three different independent experiments. No HWP1 transcripts were detected in C. dubliniensis, C. glabrata, C. krusei, and C. lusitaniae (Figure 1).

Double DNA bands were seen following agarose gel electrophoresis, indicating the nonspecific products. Thus, optimization of the PCR annealing temperature was carried out to determine the suitable temperature for specific binding of HWP1 primer. Following optimization, it was found that the specific primer of HWP1 required an ideal temperature of between 61°C to 63°C in order to obtain a specific product of 572 bp (Figure 2).

Our study has found that exposing the candidal cells to the aqueous extracts of P. betle and B. javanica apparently has affected the expression of HWP1 transcripts with increased...
extract concentrations. *C. albicans, C. parapsilosis* and *C. tropicalis* have demonstrated different intensity of mRNA which was observed in the agarose gel. Figure 3 shows that the expression of *HWPI* in *C. albicans* was reduced in a dose-dependent manner as higher concentration of *P. betle* extract used. At 6 mg/mL the band is hardly seen. *C. tropicalis* was observed not expressing *HWPI* following exposure to 1, 3, and 6 mg/mL of *P. betle* extract.

Compared to *P. betle* treatment, *B. javanica* demonstrated a higher suppression on the transcript levels of *HWPI* in *C. albicans, C. parapsilosis*, and *C. tropicalis* (Figure 4). It was shown that *HWPI* was not detected in *C. albicans* following treatment of *B. javanica* even at 1 mg/mL. In contrast, *C. parapsilosis* and *C. tropicalis* were shown to have *HWPI* regulation. However, the expression levels were reduced upon the addition of higher concentration of *B. javanica* extract. The *HWPI* transcripts of *C. albicans, C. parapsilosis*, and *C. tropicalis* were not detected in *B. javanica* treated samples of 6 mg/mL. Findings suggest the transcription levels of *HWPI* in *Candida* species may be suppressed by the addition of the extracts and were very much dependent on its environment.

### 4. Discussion

Most microorganisms including *Candida* species have different mechanisms to adhere and invade the mucosal tissues in order to sustain their existence in the oral cavity. Several metabolic pathways or interactions could be involved between the cells and the host. Gene expression is known as the fundamental characteristic to understand the cellular functions which contribute to oral infection. Our study focuses on *HWPI* gene that code for the adhesins-associated protein in the cell wall. *ACT1* was only used as the positive control to detect *Candida* species carrying this specific gene. Hyphal growth forms of *Candida albicans* have been reported to be abundantly coated with an adhesin denoted *HWPI* (Hyphal Wall Protein 1) [23]. It has been studied in *C. albicans* but there is lack of information of its presence and expression in NCAC species [23]. Unlike other microbial adhesins which adhere through hydrophobic or lectin-like interactions, *HWPI* forms covalent attachments to proteins on human buccal epithelial cells in host tissue [24]. *HWPI* is also required as first cell surface protein in vivo for biofilm formation [7]. Furthermore, this is the first study to investigate the potential of two plant extracts—*Piper betle* and *Brucea javanica*—specifically on the regulation of *HWPI*. These two plant extracts have been reported to exhibit antifungal effect on seven oral *Candida* species [25].

In normal growth condition where sufficient nutrients are provided, *HWPI* mRNA transcripts were positively regulated in *C. albicans, C. parapsilosis*, and *C. tropicalis*. The expression of *HWPI* in these three *Candida* species indicates the ability of the cells to produce adhesins that are covalently linked to the cell wall glucan through a remnant of its glycosylphosphatidylinositol (GPI) anchor, leading to cell adhesion and biofilms formation [26]. The open reading frames (ORFs) that contain the region coding for *HWPI* can be detected by the primers (Table 1) which originally designed for *C. albicans*. This suggests that *C. parapsilosis* and *C. tropicalis* are possibly sharing the identical sequence of *HWPI* with *C. albicans*. This is contrary to a study which previously reported that *HWPI* was expressed only in *C. albicans* [23].

### Table 1: Oligonucleotide sequences of *HWPI* and *ACT1*.

<table>
<thead>
<tr>
<th>Primers</th>
<th>Sequences (5′ → 3′)</th>
<th>Temp (°C)</th>
<th>bp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward (<em>HWPI</em> For)</td>
<td>CCAATGTGATGATTACCCACA</td>
<td>60.9</td>
<td>572</td>
</tr>
<tr>
<td>Reverse (<em>HWPI</em> Rev)</td>
<td>GCTGGTAGAGACTTGACCAACCATTTG</td>
<td>61.7</td>
<td>304</td>
</tr>
<tr>
<td>Forward (<em>ACT1</em> For)</td>
<td>GGAGTTGAAAGTGGTTTGGTCAATAC</td>
<td>67.6</td>
<td>61.4</td>
</tr>
<tr>
<td>Reverse (<em>ACT1</em> Rev)</td>
<td>GCTGGAACAGAAGATTCAGG</td>
<td>60.9</td>
<td>67.6</td>
</tr>
</tbody>
</table>

* *Primer templates are chosen as prescribed in Naglik et al. [20] and Tavantie et al. [21].

*Melting temperatures are analysed using OligoAnalyzer 1.2.

*RT-PCR product size (bp, base pair).
Evidence-Based Complementary and Alternative Medicine

Figure 4: Expression of HWP1 mRNAs in C. albicans (Lane 1), C. parapsilosis (Lane 2), and C. tropicalis (Lane 3) following treatment of B. javanica at sub-MICs of 1, 3, and 6 mg/mL.

Although C. albicans and C. dubliniensis have a close phylogenetic relationship, no HWP1 transcript was detected and both species seem to have distinct capacity of the cell wall protein [23]. There are a few studies which showed that C. dubliniensis forms fewer true hyphae than C. albicans [27, 28], and the lack of HWP1 adhesins being produced may partly account for its reduced capacity to adhere and less able to establish systemic infection. This is in agreement with a recent study showed that the adhering ability of C. dubliniensis to salivary pellicle was less compared to C. albicans [25].

C. glabrata and C. albicans have the basic cell wall structure in common but displayed very distinct features ranging from the presence or absence of certain surface proteins. Unlike C. albicans, it is more dependent on lectins (EPA gene products) and exists as a multilayer structure of the yeast form [29]. Therefore, C. glabrata does not rely on the production of HWP1 to establish an infection.

Findings showed that the expression of HWP1 transcripts was drastically reduced following treatment with the extracts. The addition of extracts probably has created environmental stress and demonstrated fungistatic effect on the cells. The uptake of ions and nutrients which depend on the integrity of the cell wall may be restricted. Several regulatory elements as well as the transcription of respective genes may be deactivated while waiting for the environment to be adequate for growth. This could lessen the chance for the cells to propagate and thus inhibits the hyphal formation. This could possibly explain that the transcription of HWP1 was suppressed. The low expression of HWP1 indicates that the level of adhesins was affected by the extracts. The lack of HWP1 being produced will distort the virulence trait of the candidal cells.

5. Conclusion

The expression of HWP1 transcript may indicate the production of adhesins in C. albicans, C. parapsilosis, and C. tropicalis. The transcript levels were affected following treatments with P. betle and B. javanica extracts, suggesting that the level of adhesins being produced by the candidal cells may be lacking. Subsequently, the integrity of the cell wall will be compromised and the adhesion progress will be interrupted. Findings concluded that P. betel and B. javanica aqueous extracts have a great potential to be developed as oral health care product.

Conflict of Interests

None of the authors have any conflict of interests regarding the content of the paper.

Acknowledgments

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