

INTISARI

Streptomyces sp. GMR22 merupakan aktinobakteria yang berasal dari rizosfer tegakan kayu putih di hutan Wanagama. Isolat ini diketahui mampu menghasilkan *Volatile Organic Compounds* (VOCs) dan mempunyai aktivitas antijamur, akan tetapi belum diketahui karakter VOCs nya secara detail. Penelitian ini dilakukan untuk mengkarakterisasi VOCs yang meliputi dampak VOCs terhadap pertumbuhan jamur patogen tanaman, komposisi senyawa yang ada dalam VOCs, VOC yang paling berperan sebagai antijamur, dan pengaruh medium pertumbuhan *Streptomyces* sp. GMR22 terhadap biosintesis VOC. Pengujian VOCs sebagai antijamur dilakukan menggunakan metode uji tangkup untuk mengetahui kemampuan penghambatannya terhadap pertumbuhan *Fusarium oxysporum* dan *Ganoderma boninense*. Penghambatan pertumbuhan jamur dan dampak VOCs pada morfologi miselium *F. oxysporum* dan *G. boninense* diamati menggunakan *Scanning Electron Microscopy* (SEM). Identifikasi VOCs dilakukan dengan menumbuhkan *Streptomyces* sp. GMR22 pada medium padat dalam tabung dan VOCs yang terbentuk dianalisis menggunakan *Solid Phase Microextraction-Gas Chromatography Mass Spectrometry* (SPME-GCMS). Penentuan VOC yang paling berperan sebagai antijamur dilakukan menggunakan metode *molecular docking* yang menarget β -tubulin dan hasilnya dikonfirmasi dengan pengujian IC_{50} menggunakan senyawa komersial. Pengaruh medium pertumbuhan terhadap biosintesis VOC khususnya senyawa yang paling berperan sebagai antijamur, dilakukan dengan menganalisis VOCs yang dihasilkan dan analisis transkriptomik dari gen yang terlibat dalam biosintesis VOCs. Hasil pengujian VOCs sebagai antijamur menunjukkan adanya penghambatan terhadap *F. oxysporum* sebesar 62,69%, dan *G. boninense* sebesar 50,61%, selain itu hifa kedua jamur tersebut mengalami pengkerutan dan koloninya tumbuh abnormal. Terdapat 43 VOCs yang dihasilkan *Streptomyces* sp. GMR22 dan didominasi senyawa golongan seskuiterpenoida, terpenoida dan hidrokarbon dengan proporsi berturut-turut 58%; 11,6%; 6,9%. Salah satu seskuiterpenoida yaitu *longifolene* membutuhkan energi yang paling rendah dalam berikatan dengan β -tubulin (-7,08 kcal/mol), dan IC_{50} terendah dalam menghambat pertumbuhan jamur yaitu $9,62 \pm 0,5 \mu\text{L/mL}$ dan $7,50 \pm 0,9 \mu\text{L/mL}$ pada *F. oxysporum* and *G. boninense*. Kandungan *longifolene* tertinggi (3,63%) dihasilkan oleh *Streptomyces* sp. GMR22 di medium pertumbuhan ISP2 dibandingkan dengan medium lain yang digunakan. Hasil analisis transkriptomik menunjukkan bahwa gen-gen yang terlibat dalam biosintesis *longifolene* mengalami *upregulated* (diaktifkan) saat *Streptomyces* sp. GMR22 ditumbuhkan di medium ISP2. Berdasarkan uraian di atas, dapat disimpulkan bahwa *Streptomyces* sp. GMR22 mampu menghambat pertumbuhan *F. oxysporum* dan *G. boninense* melalui VOCs yang dihasilkan dan *longifolene* merupakan VOC yang paling berperan sebagai antijamur. Penghambatan pertumbuhan kedua jamur tersebut diduga terjadi melalui proses pengikatan *longifolene* pada protein β -tubulin yang berperan pada mitosis. Biosintesis VOCs terutama *longifolene* oleh *Streptomyces* sp. GMR22 sangat dipengaruhi oleh medium pertumbuhan. Oleh karena itu perlu dilakukan

penelitian lebih lanjut terkait rekayasa medium pertumbuhan dan *metabolic engineering* untuk meningkatkan produksi *longifolene*.

Kata Kunci: Antijamur, *Fusarium oxysporum*, *Ganoderma boninense*, *Streptomyces* sp. GMR22, Transkriptomik, dan VOCs.

ABSTRACT

Streptomyces sp. GMR22 is known to be able to produce volatile organic compounds (VOCs) and has antifungal activity, but the detailed character of the VOCs is not yet known. This research was conducted to characterize VOCs, which include the impact of VOCs on the growth of plant pathogenic fungi, the composition of compounds in VOCs, VOCs that play the most role as antifungals, and the effect of growth medium on VOC biosynthesis. The assay of VOCs as antifungals was carried out using the double-dish sets to determine their ability to inhibit the growth of *Fusarium oxysporum* and *Ganoderma boninense*. Inhibition of fungal growth was observed by measuring the fungus growing on an agar medium diameter, and the impact of VOCs on the morphology of the mycelium of *F. oxysporum* and *G. boninense* was observed using Scanning Electron Microscopy (SEM). Identification of VOCs was carried out by culturing *Streptomyces* sp. GMR22 on solid medium in the vial and the formed VOCs were analyzed using solid phase microextraction-gas chromatography mass spectrometry (SPME-GCMS). The determination of the most active VOC as an antifungal was carried out using a molecular docking method that targets β -tubulin, and the results were confirmed by IC_{50} calculation. The effect of growth medium on the biosynthesis of VOCs, especially those compounds that most act as antifungals, was carried out by analyzing the VOCs produced and the transcriptomics of the genes involved in the biosynthesis of VOCs. The results of testing VOCs as antifungals showed inhibition of *F. oxysporum* by 62.69%, and *G. boninense* by 50.61%; the mycelia of the two fungi were shriveled and grew abnormally. The pink pigment is not formed in *F. oxysporum*. There were 43 VOCs produced by *Streptomyces* sp. GMR22 and dominated by sesquiterpenoids, terpenoids, and hydrocarbons, with a proportion of 58%, 11.6%, and 6.9%, respectively. One of the sesquiterpenoids, namely longifolene, requires the lowest energy in binding to β -tubulin (-7.08 kcal/mol) and the lowest IC_{50} in inhibiting fungal growth, namely $9.62 \pm 0.5 \mu\text{L/mL}$ and $7.50 \pm 0.9 \mu\text{L/mL}$ in *F. oxysporum* and *G. boninense*. The highest longifolene content (3.63%) was produced by *Streptomyces* sp. GMR22 in ISP2 growth medium. The results of the transcriptomic analysis showed that the genes involved in longifolene biosynthesis were upregulated (activated) when *Streptomyces* sp. GMR22 was grown on the ISP2 medium. Based on the description above, it is concluded that *Streptomyces* sp. GMR22 can inhibit the growth of *F. oxysporum* and *G. boninense* through the VOCs produced, and longifolene is the most VOC acting as an antifungal. The inhibition of the growth of these two fungi might occur through the process of binding longifolene to the β -tubulin protein, which plays a role in mitosis. Biosynthesis of VOCs, especially longifolene by *Streptomyces* sp. GMR22 was strongly influenced by the growth medium. Therefore, it is necessary to carry out further research related to optimizing growth media so that longifolene production is more optimal.

Keywords: Antifungal, *Fusarium oxysporum*, *Ganoderma boninense*, *Streptomyces* sp. GMR22, Transcriptomics, and VOCs