Journal of Applied Pharmaceutical Science Vol. 10(11), pp 001-009, November, 2020
Available online at http://www.japsonline.com
DOI: 10.7324/JAPS.2020.10111
ISSN 2231-3354

Isolation, structure elucidation, and antidiabetic test of vicanicin compound from lichen *Teloschistes flavicans*

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ARTICLE INFO

Received on: 10/06/2020
Accepted on: 30/08/2020
Available online: 05/11/2020

Key words:
Lichen, *Teloschistes flavicans*, antidiabetic, α-glucosidase, vicanicin.

ABSTRACT

Teloschistes flavicans is a lichen genus of the Teloschistaceae family with the orange-yellow color making it a very distinctive species. Recently, *T. flavicans* has been used as a natural medicinal ingredient because it contains several secondary metabolites to treat diseases. Thus, the aim of this study is to show the antidiabetic activity and isolation of secondary metabolite compounds from *T. flavicans*. Extraction, separation, and purification were conducted by using acetone solvent and separation was conducted by using column gravity combined with thin layer chromatography. Based on these results, we discovered the secondary metabolites of *T. flavicans* by the appearance of pure white crystal needles. Moreover, it was tested using liquid chromatography-mass spectroscopy/MS, Fourier-transform infrared spectroscopy, and 1D-NMR spectroscopy (1H and 13C) and comparison with several studies shows that the secondary metabolite vicanicin was obtained with the molecular formula $C_{18}H_{16}Cl_2O_5$. Subsequently, the antidiabetic activity of *T. flavicans* was investigated by estimating the level of non-enzymatic antioxidants from α-glucosidase with an IC_{50} value of 197.04 µg/ml. This research provides a perspective on the natural products of lichen *T. flavicans*, which have the potential as antidiabetic medicine.

INTRODUCTION

A recent study on natural phytopharmacy has attracted researchers to explore new medicines based on various types of medicinal plants, such as their uniqueness, benefits, and local wisdom (habitat and endemic location) (Pit'ay *et al*., 2019; Rohman *et al*., 2019). One of the types, local wisdom, has a unique appeal and exploration to observe the potential of medicinal plants from various countries (Rahardi, 2020). Indonesia is a mega-biodiverse country with a diversity of plants and organisms that have a high potential for exploration of natural products as medicinal ingredients (Sosilawaty, 2020; Yuniati *et al*., 2019). What is more, Indonesia is a tropical country that easily grows a variety of plants due to high sun exposure for high photosynthesis.

At present, the exploration of secondary metabolites from the plant has been studied based on the classification of algae and fungi because it produces the same secondary metabolite product (O'Neill, 2020; Selvakumar *et al*., 2020). It was identified for studying several active compounds from medicinal plants and will be developed for the basis of producing synthetic drugs (Yanuar *et al*., 2011). One of the unique organisms of lichen has attracted attention because it contains various types of secondary metabolites that are medicinal (Huneck and Yoshimura, 1996). Particularly, its symbiotic mutualism with algae (cyanobacteria) and fungi is very essential for exploring natural materials (Lutzoni *et al*., 2001; Maulidiyah *et al*., 2011).

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According to the latest research studies by Londoñe-Bailon *et al*. (2019) and Nguyen *et al*. (2020), the lichen contains bioactive compounds, such as eumitrins C-E (xanthones), alkaloids, flavonoids, and terpenoids, that have high antibacterial, antioxidant, and cytotoxic activity. In our previous study, we also reported on bioactive compounds, such as 3-[1′-(2″,3″-dihydroxy-phenyl)-propyl]-7-hydroxy-chroman-4-one (Maulidiyah *et al*., 2018), (5E,6E) 5-ethylidene-7-formyl-6,7-hydroxy methyl hept-6-enoate (Maulidiyah *et al*., 2016b), Eumitrin A1 (Maulidiyah *et al*., 2015), 2′-hydroxy-1′-(4-hydroxyl-5-methoxy-2-methyl-phenyl)-etone (Maulidiyah *et al*., 2011), and atranorin (Maulidiyah *et al*., 2016a).

The urgency and novelty of this study is the importance of exploring secondary metabolite compounds from mosses, such as *Teloschistes flavicans*, as a natural medicine to treat several human diseases, especially for their antidiabetic activity. We present the exploration of a bioactive compound (vicanicin) and observe the antidiabetic activity potential from lichen *T. flavicans*. It contains the chemical structures of chlorodepsidone, fatty acids, and polysaccharides present in apo-symbiotically cultured myco- and photobionts in the intact thallus and potential for the antidiabetic agent through the inhibitory activity of carbohydrate hydrolysis enzymes, namely α-amylase and α-glucosidase (Bate *et al*., 2018; Reis *et al*., 2005; Ruthes *et al*., 2008; Umeno *et al*., 2016).

From the literature reviews, we observed more than 22 lichen extracts have the potential as antidiabetics, likes *Everniastrum cirrhatum*, *Usnea sinensis*, *Ramalina conduplicans* Vain., *R. hossei*, *R. sinensis*, *Parmotremapseudo tinctorum*, *Flavoparmelia caperata*, *Physcia aipolia*, *Heterodermia leucomela*, *Herpothallon* sp., *P. Reticulatum*, *P. tinctorum*, *U. articulate*, *R. pollinaria*, *R. hyrcana*, *Cladoniarei*, *P. chinense*, *Punctelia subrudecta*, *Punctelia borreri*, *Hyperphysciaadglutinata*, and *Peltigera praetextata* (Hengameh *et al*., 2016; Salin Raj *et al*., 2014; Shivanna *et al*., 2015; Valadbeigi and Shaddel, 2016; Vinayaka *et al*., 2013). The extracted lichen and bioactive compounds acted as antidiabetics based on the polyphenol compound group (Thadhani and Karunaratne, 2017). Based on the potential of lichens as natural phytopharmaceuticals, it is necessary to examine the bioactivity compounds from lichen *T. flavicans* which are still underreported in the chemical compounds for its application as an antidiabetic. The α-glucosidase inhibitory activity is seen as one of the most effective therapeutic approaches in reducing blood glucose levels.

EXPERIMENTAL METHOD

Extraction of lichen T. flavicans

A sample of lichen *T. flavicans* was collected from the pine forest in Latimojong Village, Pasui District, Enrekang Regency, South Sulawesi, Indonesia. It was cleaned, dried, and mashed to eliminate the impurities. Then, it was weighed (560 g) and extracted by using acetone solvent (Merck, Germany) for 3 × 24 hourss (maceration process). Every 24 hours, the lichen extract was filtered to separate the filtrate and residue. This technique was repeated three times and the aim of the high-extraction process was to get the extracted lichen compound. The acetone extract was separated by using a rotary vacuum evaporator to produce high concentrates.

Separation and purification

The lichen extract was tested by using the thin layer chromatography (TLC) method to identify and determine variations in eluent ratios that can be used in gravity column chromatography (GCC) (Table 1), with a column size of 50 ml and a diameter of 2 cm. The preparation of GCC was carried out by weighing 160 g of silica gel mixed with n-hexane solvent (Merck, Germany) and put in a GCC tube. On the other hand, the lichen extract was impregnated by weighing as much as 6 g containing silica gel in a ratio of 1: 1 *w/w*. The sample was eluted in a GCC tube in a solvent gradient as shown in Table 1. Every 250 ml of the lichen extract was put into a vial glass and evaporated to observe the crystal product. After that, 27 eluents were collected and tested on a TLC plate to review specific color spot by calculating the Rf value under ultraviolet (UV) irradiation at 254 and 365 nm, to determine if it has produced the specific color spot that provides a description of secondary metabolites found.

Identification of the bioactive compound

The isolated compound was analyzed using liquid chromatography-mass spectroscopy (LC–MS) (LCMS 8060 System) to review the molecular weight and provide the structural identity of each component with high molecular specificity and detection sensitivity. Also, Fourier-transform infrared spectroscopy (FTIR) (Shimadzu IR Affity-1S system) was used to observe a typical absorption band at the wavenumber and confirmed using 1D-nuclear magnetic resonance [(NMR) (1H and 13C)] (JEOL JNM ECA 500). Referring to these data, we interpret by comparison with the literature reviews.

Bioactivity test

Toxicity test for A. salina *leach shrimp larvae*

Initial testing to overview the extracted toxicity compound was applied by using the Meyer method under A. *salina* Leach (shrimp larvae) (Meyer *et al*., 1982). The LC_{50} value is calculated based on the equation: $y = ax + b$, where y states that the shrimp larvae have died 50% after 24 hours of incubation. Meanwhile, a and b values are data regressions based on a slope with concentration variations as the standard method. Then, we can calculate the value of x concentration to inhibit the larvae based on 50% mortality. The substance is active/toxic when the LC_{50} value is ≤ 1,000 µg/ml (Meyer *et al*., 1982).

Antidiabetic activity test

Antidiabetic activity test was conducted by inhibiting the enzyme α-glucosidase that has been previously reported by Dewi *et al*. (2012) and Kim *et al*. (2008). A positive control using 1 mg of quercetin dissolved in 100 µl dimethyl sulfoxide (DMSO) was diluted with four variations of concentration to obtain a standard curve. The positive control was tested with the addition of or without enzyme solution. Meanwhile, the negative controls were prepared without the addition of 5 µl DMSO. Finally, we can calculate this with the following equation:

Inhibitory activity (%) = , (1)

where K is the absorbance of the negative control solution, S is the absorbance of test solution or positive control

solution, and [$S = S_1$ (absorbance with the addition of enzymes) - S_0 (absorbance without adding enzymes)].

RESULTS AND DISCUSSION

Isolation of lichen T. flavicans

The concentrated extract was identified by phytochemical screening to determine the classification of chemical compounds in *T. flavicans*, which were confirmed as alkaloids, flavonoids, saponins, tannins, and terpenoids, presented in Table 2.

Through the elution process, we obtained 136 eluates with various eluent systems (Table 1). They were tested by using TLC to view patterns of a color spot under UV irradiation at 254 and 365 nm. Several organic compounds containing heterocyclic-electron are conjugated when exposed to UV light. So, we can determine the Rf value on the TLC plate and deduce a single spot. After recrystallization in fraction 2 (F2) (Table 3) and evaporation, it produced white needle-shaped crystals (Fig. 1).

Identification of the bioactive compound

White crystal needles were characterized by using the LC–MS/MS chromatogram (Fig. 2), showing a peak at *m/z* 383. We can deduce the molecular weight of the isolated compound to be 383 g mol^{-1}. Some chemical compounds of the lichen identified in *m/z* 383 are a depsidone group which enriches the –OH and O groups. LC–MS analysis only identifies the molecular weight of a compound to inform the total atoms in the isolated compound.

To predict the chemical groups in the isolated compound, we used FTIR (Fig. 3), which shows that there was a typical absorption band (wavenumber) at 3,511 cm^{-1} from the –OH (hydroxyl) group. Then, it showed a C-O stretch of the C-O-C ether group under wavenumbers 2,963 and 1,096 cm^{-1} (fingerprint

Table 1. The eluent system used in column chromatography and the eluate obtained.

Number	Eluent comparison (%)			Total eluent volume (ml)	Eluent arrangement
	n-Hexane	Ethyl acetate	Methanol		
1.	100	0	0	2,000	1–8
2.	97.5	2.5	0	2,000	9–16
3.	95	5	0	3,000	17–28
4.	92.5	7.5	0	2,000	29–36
5.	90	10	0	1,000	37–44
6.	85	15	0	1,000	45–48
7.	80	20	0	1,000	49–52
8.	75	25	0	1,000	53–56
9.	70	30	0	1,000	57–60
10.	65	35	0	1,000	61–65
11.	60	40	0	1,000	66–69
12.	55	45	0	1,000	70–73
13.	50	50	0	1,000	74–77
14.	45	55	0	1,000	78–81
15.	40	60	0	1,000	82–85
16.	35	65	0	1,000	86–89
17.	30	70	0	1,000	90–94
18.	25	75	0	1,000	95–98
19.	20	80	0	1,000	99–102
20.	15	85	0	1,000	103–106
21.	10	90	0	1,000	107–110
22.	5	95	0	1,000	111–114
23.	0	100	0	1,000	115–118
24.	0	90	10	1,000	119–122
25.	0	80	20	1,000	123–126
26.	0	70	30	1,000	127–131
27.	0	60	40	1,000	132–136

Table 2. Phytochemical screening of the acetone extract for lichen *T. flavicans.*

Sample	Compound content				
	Alkaloid	Flavonoid	Saponin	Tannin	Terpenoid
Lichen *T. flavicans* extract (acetone extract)	+	+	+	+	+

Table 3. The combined fractions of eluate and fraction mass.

Number	Combined eluate	Fraction	Mass fraction (gram)
1	1–10	F1	0.1237
2	11–13	F2	0.1712
3	14–18	F3	0.5757
4	19–24	F4	1.4038
5	25–31	F5	0.4551
6	32–44	F6	0.3348
7	45–59	F7	0.7616
8	60–82	F8	0.4315
9	83–91	F9	0.2469
10	92–110	F10	1.1420
11	111–119	F11	0.1149
12	120–136	F12	1.0652

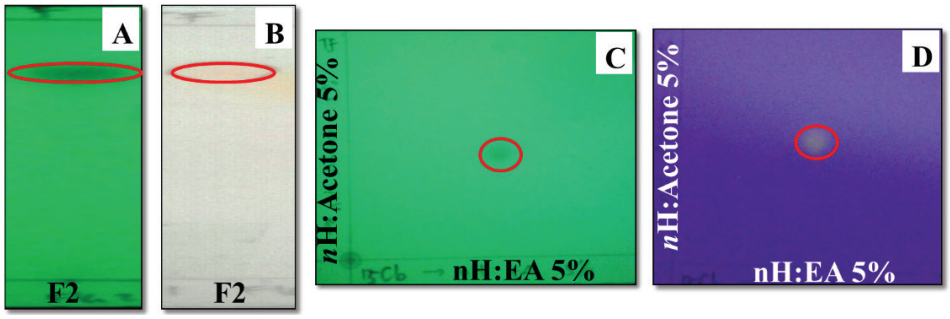


Figure 1. TLC of isolate compound F2: (A) chromatogram under UV 365 nm; (B) after spraying 5% H_2SO_4; (C) 2-dimensional TLC chromatogram under UV 254 nm; and (D) under UV 365 nm.

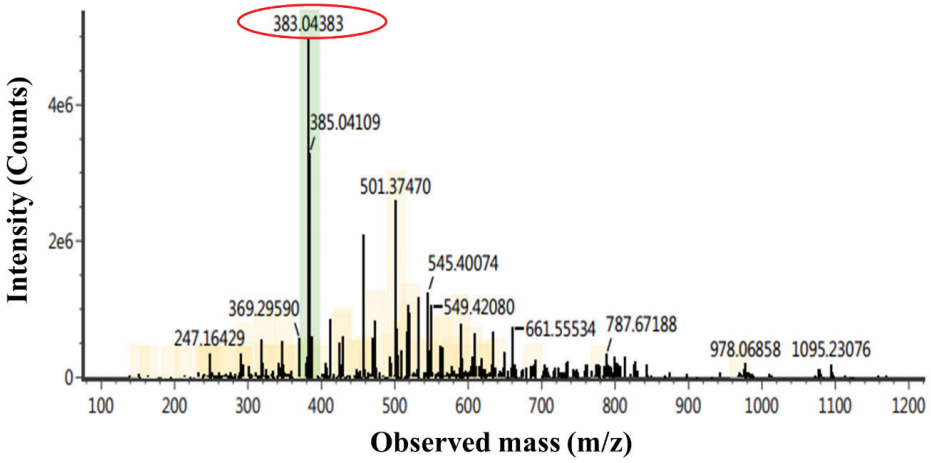


Figure 2. LC–MS/MS chromatogram of the isolated compound.

area). The strong intensity at wavenumber 2,744 cm^{-1} indicates the carbonyl group C=O. The presence of an aromatic ring at wavenumber 1,595 cm^{-1} and buckling bond is confirmed by the cyclic form at wavenumbers 1,437 and 1,359 cm^{-1} (methylene and methyl groups, respectively). On the other hand, we also discover two halogen groups (C–Cl) as hydrogen bridges with the –OH group at wavenumbers of 843 and 729 cm^{-1}. The presence of two chlorine atoms is strengthened by the fragment peaks in LC–MS with *m/z* 383 and 385 with the lower left to right intensity ratio which is characteristic of two chlorine atoms (Kadivar *et al*., 2011). Based on the FTIR spectrum analysis, the isolated compound had similar absorption data as the vicanicin compound (Huneck and Yoshimura, 1996).

In addition, 1D-NMR was applied to confirm the chemical structure of the isolated compound. The determination of the atomic structure is presented at ^{1}H and ^{13}C based on the

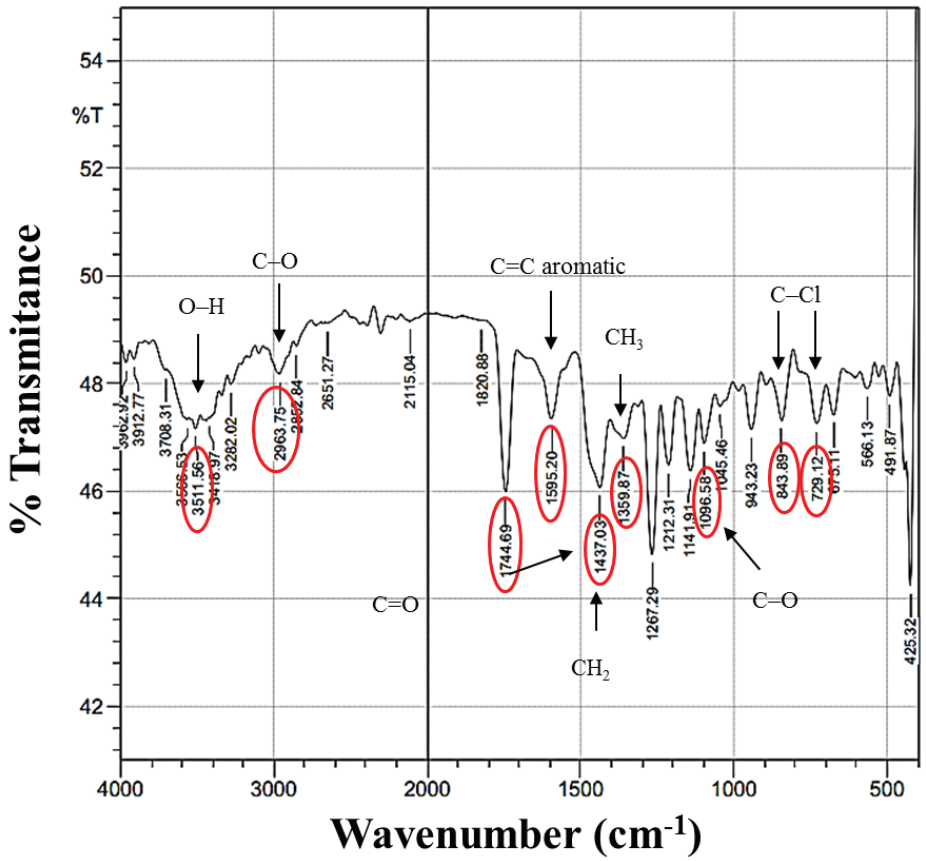


Figure 3. FTIR spectrum of the isolate compound.

position of the H and C atoms. According to Figure 4, ^{1}H-NMR analysis shows that the isolated compound contains 16 hydrogen atoms with the appearance of a single signal. The chemical shift of δH = 6.95 ppm indicates the –OH group and δH = 3.86 ppm indicates the presence of methoxy group (–OCH_3) which are attached to the aromatic ring. Then, the chemical shift at 2.55, 2.49, 2.422, and 2.421 ppm shows four methyl groups attached to the aromatics.

Furthermore, an analysis of ^{13}C-NMR (Fig. 5) shows that the isolated compound contained 18 carbon atoms at a chemical shift (δC) of 60.84 ppm, indicating one carbon atom in the methoxy group. The methyl group was confirmed at a chemical shift of 18.59, 15.25, 11.27, and 11.26 ppm and the carbonyl group was presented at δC = 162.96 ppm, which also appears in the IR spectrum of 1,744 cm^{-1}. Moreover, signals from aromatic groups (C=C atom) were confirmed at chemical shifts of 139.00 and 144.50 ppm. Based on the interpretation of data compared with several other literature studies (Huneck and Yoshimura, 1996; Sargent *et al*., 1976), we conclude that the isolated compound was vicanicin with the molecular formula of $C_{18}H_{16}Cl_2O_5$.

The number of double bonds and rings in the isolated compound has been determined by the hydrogen deficiency index formula (Wang *et al*., 2012). The calculation of double bonds or ring number was obtained with an F value of 10 derived from 1 carbonyl group (C=O) and 6 double bonds of C=C in two aromatic rings. Three rings have been identified wherein two are aromatic rings and one is a nonaromatic ring of the carbonyl group.

Based on the comparison of physical properties and spectrum data of the isolated compound, they have the same data and similarity properties as the vicanicin compound. It is a depsidone group that previously has been isolated from lichen *Ramalina javanica* Nyl (Pranadita andYuliani, 2019; Sargent *et al*., 1976). The structural formula of vicanicin is shown in Figure 6.

Bioactivity test

Information of the bioactivity test inhibiting A. *salina* Leach and α-glucosidase enzyme is shown in Tables 5 and 6. Based on Table 5, the vicanicin compound has high toxicity against A. *salina* Leach because it contains cyclic groups, carbonyl groups, and oxygen bridges. Suryani *et al*. (2019) have reported that the role of the cyclic structure and carbonyl groups can inhibit high toxicity to A. *salina* Leach.

Table 6 shows the test results of α-glucosidase enzyme activity by comparing the performances of quercetin, *T. flavicans* extract, and vicanicin compound. The quercetin as the positive control has a high inhibition compared to the *T. flavicans* extract and vicanicin with an IC_{50} value of 4.05, 54.05, and 197.04 µg/ml, respectively. However, vicanicin has a lower activity because it does not contain many hydroxyl groups or an active role in inhibiting the α-glucosidase enzyme. The *T. flavicans* extract has shown good stability because it still contains a variety of chemical

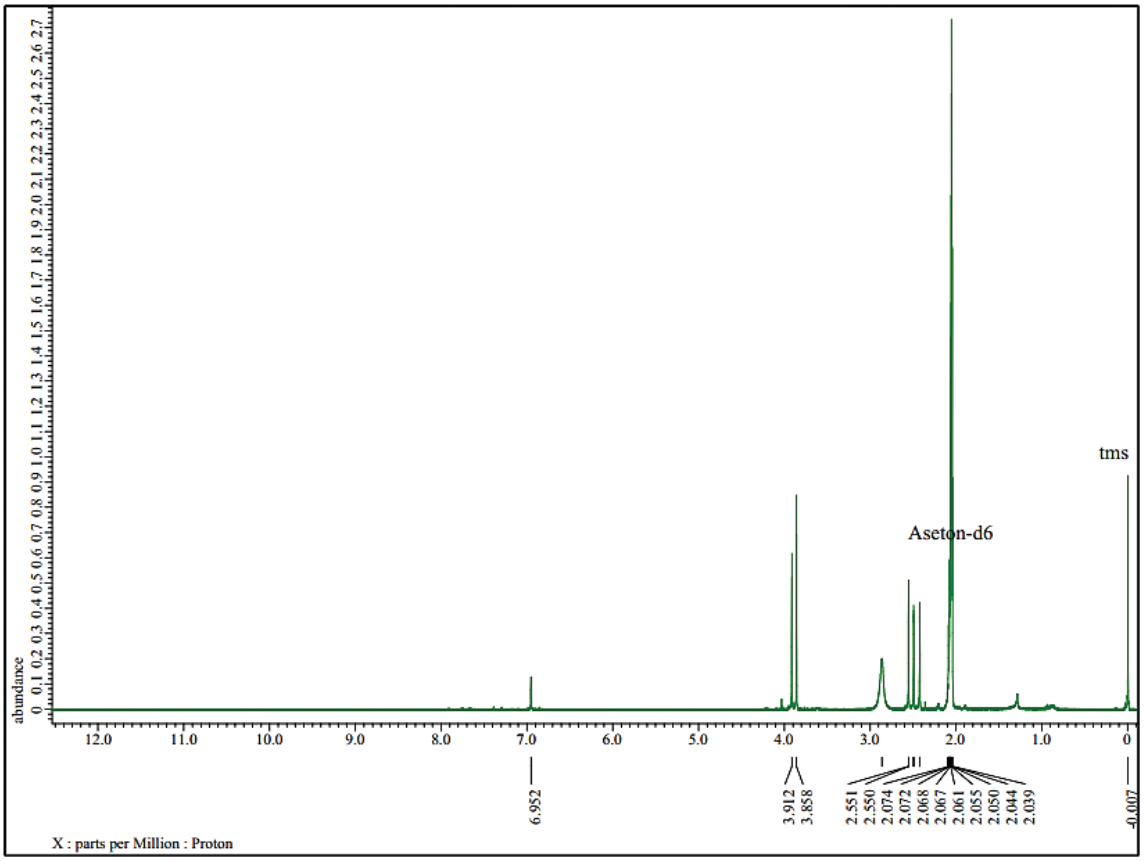


Figure 4. [1]H-NMR spectra of the isolated compound.

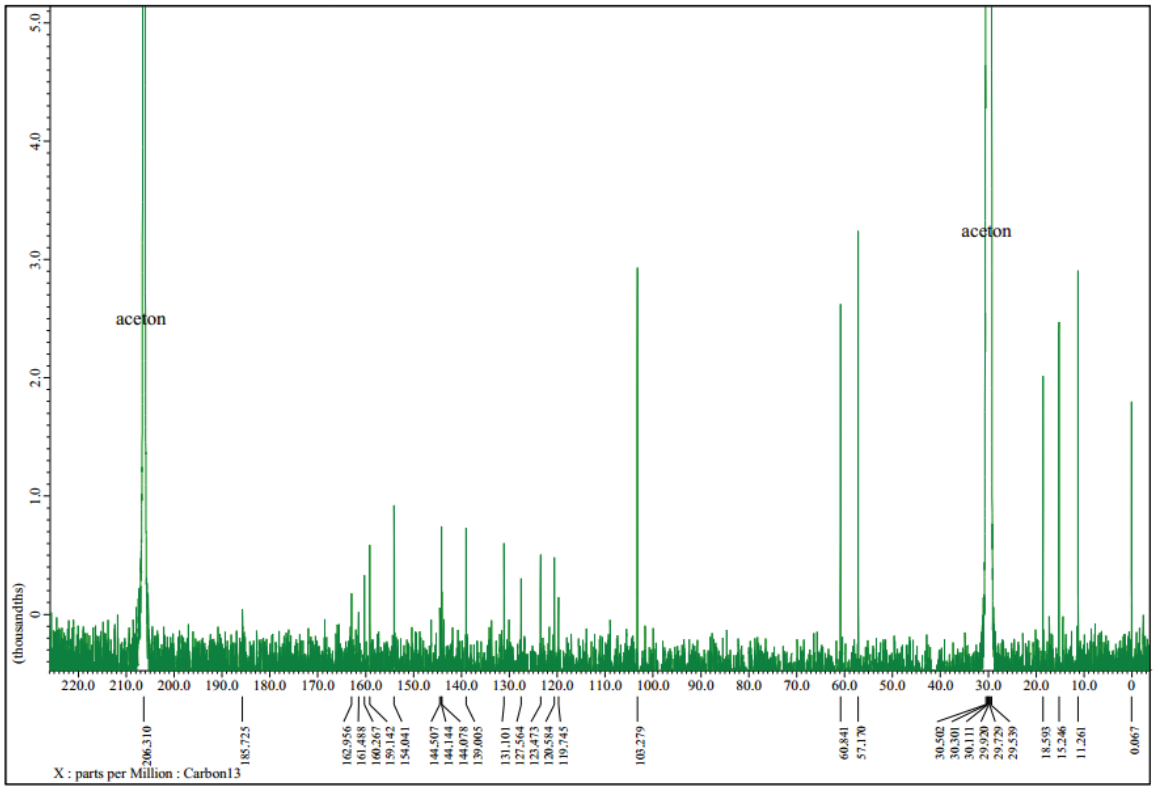
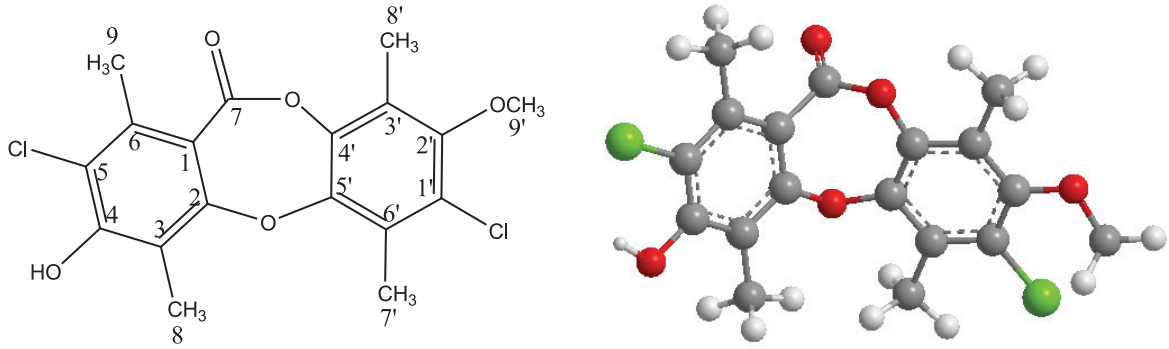


Figure 5. [13]C-NMR spectrum of the isolated compound.



(1D structure of vicanicin compound) (3D structure of vicanicin compound)

Figure 6. Structure of the vicanicin compound.

Table 4. Comparison of shifting chemical data of ^{1}H-NMR and ^{13}C-NMR isolated compound and vicanicin.

Position C	Isolated compound		Vicanicin	
	δ_H (ppm)	δ_C (ppm)	δ_H (ppm)	δ_C (ppm)
1		119.75		115.33
2		160.26		159.52
3		103.28		114.41
4	6.95 (s)	159.14	6.21 (s)	153.45
5		139.00		138.14
6		119.76		118.68
7		162.96		162.70
8	2.422 (s)	11.26	2.45 (s)	10.65
9	2.49 (s)	18.59	2.52 (s)	18.50
1′		144.50		146.42
2′		154.04		152.05
3′		120.59		122.39
4′		144.08		142.03
5′		127.56		126.77
6′		123.47		125.20
7′	2.55 (s)	15.25	2.59 (s)	14.74
8′	2.421 (s)	11.27	2.41 (s)	10.24
9′	3.86 (s)	60.84	3.75 (s)	60.38

Table 5. The toxicity test results of the Brine Shrimp lethality test method on the isolate.

Sample	K (µg/ml)	Log K	Dead	Alive	Accumulation		Mortality	LC_{50} (µg/ml)
					M	H		
Control	0	0	0	10	0	40	0	
	0	0	0	10	0	30	0	–
	0	0	0	10	0	20	0	
	0	0	0	10	0	10	0	
	10	1	1	29	1	31	3.13	
Vicanicin	100	2	28	2	29	2	93.55	13.07
	500	2.7	30	0	59	0	100.00	

Tabel 6. Data test results for α-glucosidase enzyme inhibitory activity.

Sample	Concentration (µg/ml)	Inhibition (%)	IC_{50} (µg/ml)
Positive control of quercetin	12.5	75.46	4.05
	6.25	64.46	
	3.125	43.43	
	1.5625	25.20	
Lichen *T. flavicans* extract	100	65.49	54.05
	50	49.85	
	25	29.99	
	12,5	5.51	
Vicanicin	12.5	−18.96	197.04
	6.25	−21.52	
	3.125	−22.41	

compounds that synergize to inhibit the α-glucosidase enzyme (Li *et al*., 2005), while vicanicin is a single compound although it is weak in inhibiting the α-glucosidase enzyme, making an impact as a potential for antidiabetic activity (Wang *et al*., 2012). With the chemical structure approach, vicanicin also does not have oxidative properties to inhibit α-glucosidase activity which is characterized by presenting oxygen atoms (Stojanovic *et al*., 2012). According to Gong *et al*. (2017), secondary metabolites with natural antioxidant properties have the ability to inhibit α-glucosidase as a type 2 diabetes treatment.

CONCLUSION

The secondary metabolite compound vicanicin was isolated from lichen *T. flavicans*, with the molecular formula $C_{18}H_{16}Cl_2O_5$. Current information about toxicity of *A. salina* Leach larvae also shows that the antidiabetic potential of *T. flavicans* extract has toxicity to *A. salina* with an LC_{50} value < 1,000 µg/ml, which is 9.38 µg/ml. Meanwhile, vicanicin compounds also showed toxicity, with an LC_{50} value of 13.07 µg/mL. The antidiabetic test showed that the *T. flavicans* extract gave the highest inhibition compared to the vicanicin compound, with IC_{50} values of 54.05 and 197.04 µg/ml, respectively. The hydroxyl group contains reactive oxygen compounds in *T. flavicans* extract which play an important role in inhibiting the larvae of *A. salina* Leach to lyse cell membranes and decide the chemical bonds in the α-glucosidase enzyme. This study provides a perspective on the natural products of lichen *T. flavicans* extract, which have the potential as antidiabetic drugs.

ACKNOWLEDGMENT

The authors acknowledge the financial support from the DRPM-Ministry of Research, Technology and Higher Education of the Republic of Indonesia under the World Class Research 2020 Grant no. 171/SP2H/AMD/LT/DRPM/2020.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Bate PNN, Orock AE, Nyongbela KD, Babiaka SB, Kukwah A, Ngemenya MN. *In vitro* activity against multi-drug resistant bacteria and cytotoxicity of lichens collected from mount cameroon. J King Saud Univ Sci, 2018; 32(1):614–9.

Dewi RT, Tachibana S, Darmawan A. Antidiabetic and antioxidative activities of butyrolactone I from *Aspergillus terreus* MC751. World Acad Sci Eng Technol, 2012; 70:882–7.

Gong Y, Qin XY, Zhai YY, Hao H, Lee J, Park YD. Inhibitory effect of hesperetin on α-glucosidase: molecular dynamics simulation integrating inhibition kinetics. Int J Biol Macromol, 2017; 101:32–9.

Hengameh P, Rashmi S, Rajkumar HG. *In vitro* inhibitory activity of some lichen extracts against α-amylase enzyme. Eur J Biomed Pharm Sci, 2016; 3:315–8.

Huneck S, Yoshimura I. Identification of lichen substances. In: Identification of lichen substances. Springer, Berlin, Germany, pp 11–123, 1996.

Kadivar MH, Sinha PK, Kushwah D, Jana P, Sharma H, Bapodra A. Study of impurity carryover and impurity profile in Febuxostat drug substance by LC–MS/MS technique. J Pharm Biomed Anal, 2011; 56:749–57.

Kim KY, Nam KA, Kurihara H, Kim SM. Potent α-glucosidase inhibitors purified from the red alga grateloupia elliptica. Phytochemistry, 2008; 69:2820–5.

Li Y, Wen S, Kota BP, Peng G, Li GQ, Yamahara J, Roufogalis BD. Punica granatum flower extract, a potent α-glucosidase inhibitor, improves postprandial hyperglycemia in Zucker diabetic fatty rats. J Ethnopharmacol, 2005; 99:239–44.

Londoñe-Bailon P, Sánchez-Robinet C, Alvarez-Guzman G. *In vitro* antibacterial, antioxidant and cytotoxic activity of methanol-acetone extracts from Antarctic lichens (*Usnea* antarctica and *Usnea* aurantiaco-atra). Polar Sci, 2019; 22:100477.

Lutzoni F, Pagel M, Reeb V. Major fungal lineages are derived from lichen symbiotic ancestors. Nature, 2001; 411:937–40.

Maulidiyah A, Cahyana H, Suwarso WP, Nurdin M. Isolation and structure elucidation of Eumitrin A_1 from lichen *Usnea* blepharea motyka and its cytotoxic activity. Int J Pharm Tech Res, 2015; 8:782–9.

Maulidiyah I, Watu M, Nurdin M. Secondary metabolites identification from lichen Usnea longissima Ach: bioactivity test of antibacterial. Int J Appl Chem, 2016b; 12:347–57.

Maulidiyah M, Cahyana AH, Suwarso WP. A new phenolic compound from acetone extract of lichen *Usnea* flexuosa Tayl. Indones J Chem, 2011; 11:290–4.

Maulidiyah M, Hasan A, Waode I, Ishmah FAN, Tuty K, Imran, Abdul HW, Thamrin A, Akhmad D. Antifungal potential against *Aspergillus* flavus: secondary metabolite compound from unique organism of lichen *Teloschistes flavicans*. Int Res J Pharm, 2018; 9:1–6.

Maulidiyah M, Sabarwati SH, Safutra E, Nurdin ME, Nurdin M. Atranorin secondary metabolite from lichen *Usnea* sp. and its antibacterial activity. Int J Pharma Bio Sci, 2016a; 7:159–69.

Meyer BN, Ferrigni NR, Putnam JE, Jacobsen LB, Nichols DE j, McLaughlin JL. Brine shrimp: a convenient general bioassay for active plant constituents. Planta Med, 1982; 45:31–4.

Nguyen V-K, Genta-Jouve G, Duong T-H, Beniddir MA, Gallard J-F, Ferron S, Boustie J, Mouray E, Grellier P, Chavasiri W, Pogam PL. Eumitrins CE: Structurally diverse xanthone dimers from the vietnamese lichen Usnea baileyi. Fitoterapia, 2020; 141:104449.

O'Neill E. Mining natural product biosynthesis in eukaryotic algae. Mar Drugs, 2020; 18:90.

Pit'ay MF, Anggraito YU, Ngabekti S. Identifying medicinal plant in local custom nasinoah forest to develop local wisdom based learning material. J Innov Sci Educ, 2019; 8:352–9.

Pranadita KA, Yuliani Y. Potensi ekstrak lichen parmelia sulcata dalam menghambat pertumbuhan bakteri xanthomonas campestris pada tanaman kubis. LenteraBio, 2019; 8(2):162–7.

Rahardi RK. On emblematic meanings of traditional medicinal herbs: local wisdom values in the perspective of culture-specific ecopragmatics. J Arbitrer, 2020; 7:16–28.

Reis RA, Iacomini M, Gorin PAJ, de Souza LM, Grube M, Cordeiro LMC, Sassaki GL. Fatty acid composition of the tropical lichen *Teloschistes flavicans* and its cultivated symbionts. FEMS Microbiol Lett, 2005; 247:1–6.

Rohman F, Juma Y, Utomo DH, Lestari SR, Arifah SN, Putra WE. Plants diversity as a medicinal plants by the tengger tribe, bromo tengger Semeru National Park, East Java, Indonesia. Eur Asian J Biosci, 2019; 13:2293–8.

Ruthes AC, Komura DL, Carbonero ER, Cordeiro LMC, Reis RA, Sassaki GL, Gorin PAJ, Iacomini M. Polysaccharides present in cultivated *Teloschistes flavicans* symbiosis: comparison with those of the thallus. Plant Physiol Biochem, 2008; 46:500–5.

Salin Raj P, Prathapan A, Sebastian J, Antony AK, Riya MP, Rani MRP, Biju H, Priya S, Raghu KG. *Parmotrema tinctorum* exhibits antioxidant, antiglycation and inhibitory activities against aldose reductase and carbohydrate digestive enzymes: an *in vitro* study. Nat Prod Res, 2014; 28:1480–4.

Sargent MV, Vogel P, Elix JA, Ferguson BA. Depsidone synthesis. VII. Vicanicin and norvicanicin. Aust J Chem, 1976; 29:2263–9.

Selvakumar V, Singh S, Kannan K, Annamalai P. Pharmaceutically important metabolites from marine fungi. In: Bioactive natural products in drug discovery. Springer, Berlin, Germany, pp 411–425, 2020.

Shivanna R, Parizadeh H, Garampalli RH. Screening of lichen extracts for in vitro antidiabetic activity using alpha amylase inhibitory assay. Int J Biol Pharm Res, 2015; 6:364–7.

Sosilawaty M. Identifying the diversity of orchids in the Sebangau National Park in Central Kalimantan. Int J Adv Res Eng Technol, 2020; 11:185–91.

Stojanovic G, Stojanovic I, Smelcerovic A. Lichen depsidones as potential novel pharmacologically active compounds. Mini Rev Org Chem, 2012; 9:178–84.

Suryani A, Dini I. Usnic acid derivate from *Usnea* sp. and bioactivity against arthemia salina leach. Mater Sci Forum, 2019; 967:45–50.

Thadhani VM, Karunaratne V. Potential of lichen compounds as antidiabetic agents with antioxidative properties: a review. Oxid Med Cell Longev, 2017; 2017:2079697.

Umeno A, Horie M, Murotomi K, Nakajima Y, Yoshida Y. Antioxidative and antidiabetic effects of natural polyphenols and isoflavones. Molecules, 2016; 21:708.

Valadbeigi T, Shaddel M. Amylase inhibitory activity of some macrolichens in Mazandaran province, Iran. Physiol Pharmacol, 2016; 20:215–9.

Vinayaka KS, Karthik S, Nandini KC, Kekuda PTR. Amylase inhibitory activity of some macrolichens of Western Ghats, Karnataka, India. Indian J Nov Drug Deliv, 2013; 5:225–8.

Wang Y, Huang S, Shao S, Qian L, Xu P. Studies on bioactivities of tea (*Camellia sinensis* L.) fruit peel extracts: antioxidant activity and inhibitory potential against α-glucosidase and α-amylase *in vitro*. Ind Crops Prod, 2012; 37:520–6.

Yanuar A, Mun'im A, Lagho ABA, Syahdi RR, Rahmat M, Suhartanto H. Medicinal plants database and three dimensional structure of the chemical compounds from medicinal plants in Indonesia. Int J Comp Sci, 2011; 8(1):180–3.

Yuniati E, Indriyani S, Batoro J, Purwanto Y. The potential of ethnozoology in traditional treatment of bada ethnic in lore lindu biosphere reserve in central sulawesi. In IOP Conference Series: Earth and Environmental Science. IOP Publishing, Bristol, UK, 2019, p 12041.

How to cite this article:
Maulidiyah M, Darmawan A, Hasan A, Wibowo D, Salim LOA, Ansharullah A, Mustapa F, Nurdin IFA, Nurdin M. Isolation, structure elucidation, and antidiabetic test of vicanicin compound from lichen *Teloschistes flavicans*. J Appl Pharm Sci, 2020; 10(11):001–009.