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Antioxidant activity, α-glucosidase inhibition, and phytochemical profiling of *Belosynapsis ciliata* (Blume) R.S.Rao extracts

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ABSTRACT: Diabetes mellitus (DM) is a chronic metabolic disorder associated with persistent hyperglycemia. Globally, the number of people with DM has quadrupled in the past three decades, and type 2 diabetes mellitus (T2DM) accounts for around 90% of all cases of diabetes. The role of oxidative stress is well established in T2DM pathogenesis. The synthetic drugs for T2DM are associated with serious side effects. Antioxidant and α-glucosidase inhibitory actions of phytochemicals from various plant species are considered an alternative to the synthetic drugs for T2DM management. This study aimed to evaluate the antioxidant activity, α-glucosidase inhibition, and phytochemical profiling of *Belosynapsis ciliata*. The total phenolic and flavonoid contents, antioxidant activity of 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical, 2,2′-azino-bis(3-ethylbenzthiazoline-6-sulfonic acid) (ABTS) free radical, and nitric oxide (NO) radical, and α-glucosidase inhibition of *B. ciliata* extracts were determined spectrophotometrically. The ethyl acetate extract form *B. ciliata* had highly potent scavenging activities for DPPH (EC_{50}; 80.02 ± 4.34 μg/ml) and ABTS (EC_{50}; 97.07 ± 1.52 μg/ml). Meanwhile, the dichloromethane extract possessed a good scavenging of NO (IC_{50}; 121.65 ± 3.48 μg/ml) and had the highest α-glucosidase inhibitory activity (IC_{50}; 33.28 ± 1.36 μg/ml). This study demonstrated the promising antioxidant activities, and α-glucosidase inhibitory action of *B. ciliata* was probably due to the presence of phenolic and flavonoid contents. The finding provided us with the leads to proceed with the development of medicinal plant having antidiabetic attributes.

KEYWORDS: *Belosynapsis ciliata*, α-glucosidase, ABTS, DPPH, nitric oxide

INTRODUCTION

Diabetes mellitus (DM) is one of the most common metabolic disorders globally, associated with persistent hyperglycemia, and the prevalence of DM in adults has been increasing in the past three decades. More than 90% of diabetic patients are suffering from type 2 diabetes mellitus (T2DM) [1]. The role of reactive oxygen species (ROS) and oxidative stress in T2DM progression is evident from scientific studies [2]. The mechanism of action through which oxidative stress contributes to DM pathogenesis is not fully understood. However, the hyperglycemia is reported to produce free radicals which impair the insulin secretion, resulting in alteration in glucose uptake and abnormal glucose release from liver, and mediate the change in metabolic pathways [3]. High levels of ROS are also involved in glycation of proteins, lipid peroxidation, and glucose oxidation, and these collectively impart in T2DM development and related disorders [4]. Therefore, the elimination of ROS or reduction in the level of oxidative stress may diminish the chances of T2DM pathogenesis and prolongation by improving the intracellular antioxidant defense [5].

The antioxidant-based therapy is considered a promising approach to treat T2DM as antioxidants effectively scavenge the free radicals and ROS to prevent DM pathogenesis and related complications [6]. Nowadays, there are many synthetic drugs available to treat T2DM, but the side effects associated with such compounds are concerned [7]. Health related drawbacks of synthetic drugs emphasize the need to develop alternate treatments.

Many natural bioactive compounds in plants are also associated with α-glucosidase inhibition which restricts the hydrolysis of carbohydrates (i.e., disaccharides and oligosaccharides) in the intestine and restricts their absorption, consequently limiting the postprandial glucose level [8]. Plants also contain antioxidants against the marked ROS levels in the body to diminish the risks of T2DM pathogenesis and progression [9]. Phenolic compounds are important plant constituents with redox properties responsible for antioxidant activity [10]. Therefore, exploring of antioxidant and α-glucosidase inhibitor from plants for T2DM management is a workable, safe, reliable, and cost-effective approach.

Belosynapsis ciliata (Blume) R.S.Rao (Ya Pai Nam or Ya Ka Luem) is the perennial herb family Commelinaceae [11]. It is widely distributed in southern China, Malaysia, Indonesia, Philippines, Vietnam, and Thailand [12]. The whole part of *B. ciliata* has been consumed as a vegetable and used as a traditional medicine for renal dysfunction treatment caused by

DM [13]. Obviously, data indicated that the plants from Commelinaceae family are the rich source of phenolic and flavonoid compounds [14], but *B. ciliata* has rarely been reported for its pharmacological effects. Therefore, the present study aimed to evaluate the antioxidant activity, α-glucosidase inhibitory potential, and phytochemical profiling of *B. ciliata*.

MATERIALS AND METHODS

Plant collection and identification

Belosynapsis ciliata (Blume) R.S.Rao or Ya Pai Nam was collected from Ubon Ratchathani Province, Thailand, which is located at 15.24° North and 105.09° East. The plant was botanically identified by Asst. Prof. Dr. Thaweesak Titimmatharoj, Faculty of Pharmaceutical Sciences, Khon Kaen University. A voucher specimen (BK070798) was deposited at the Bangkok Herbarium, Plant Varieties Department of Agriculture, Thailand.

Plant extraction

Mature, fresh whole parts of *B. ciliata* were washed thoroughly in running tap water, then air-dried at room temperature for 1 day. The plant was cut and further dried in hot air oven at 45 °C for 5 h. They were grinded into crude powder. The *B. ciliata* extract was prepared by using Soxhlet apparatus. Thirty grams of the powder were sequentially extracted with four solvents in an increasing order of the polarity such as hexane, dichloromethane, ethyl acetate, and methanol. Four exhausted extracts were concentrated under reduced pressure by using the rotary evaporator (Buchi, Switzerland). The crude extracts were kept in vacuum desiccator at room temperature until used.

Phytochemical screening

The extracts from *B. ciliata* were qualitatively tested for different phyto-constituents, namely flavonoids, alkaloids, tannins, saponins, coumarins, anthraquinones, cardiac glycosides, and cyanogenic glycosides by following the standard protocol [14, 15].

Determination of total phenolic content

Total phenolic content (TPC) was measured using the Folin-Ciocalteu assay with some modifications by Dechayont et al [16]. The principle of this assay is the reduction of the Folin-Ciocalteu reagent in the presence of phenolics, resulting in the production of molybdenum-tungsten blue. Four crude extracts were prepared with their suitable solvent. An aliquot of 20 µl of each sample was mixed with 60 µl of ethanol, 100 µl of 0.2 M Folin-Ciocalteu's solution, and 80 µl of 7.5% sodium carbonate. The mixture was allowed to stand for 30 min at room temperature. The molybdenum-tungsten blue product was measured spectrophotometrically at a wavelength of 765 nm (Bio Tek, USA). Each reaction was done in triplicate, and the values were averaged. TPC was calculated using the standard calibration curve of gallic acid (3.5, 12.5, 25, 50, and 100 µg/ml) and expressed as gallic acid equivalent in milligram per gram of dried crude extract (mg GAE/g).

Determination of total flavonoid content

Total flavonoid content (TFC) was performed using the aluminium chloride colorimetric method with some modifications as described [16]. A 20 µl of the testing sample was gently mixed with 60 µl of ethanol, 10 µl of 10% aluminum chloride, and 10 µl of 1 M potassium acetate. After that, 120 µl of distilled water was added to the reaction solution, and then it was allowed to stand at room temperature for 30 min. Absorbance of the mixture was determined at 415 nm. Each reaction was done in triplicate, and the values were averaged. TFC of the testing solution was calculated under the standard calibration curve of quercetin (6.25, 25, 100, 200, and 400 µg/ml) and expressed as quercetin equivalent in milligram per gram of dried crude extract (mg QE/g).

Evaluation of antioxidant activities

DPPH radical scavenging assay

The direct antioxidant activity of the extracts to scavenge DPPH free radical was determined with some modifications [16]. The 100 µl of the testing solution (15, 30, 60, 120, and 240 µg/ml) was gently mixed with 100 µl of 0.06 mM DPPH solution and then allowed to stand in the dark at room temperature for 30 min. Butylated hydroxytoluene (BHT) was used as a positive control. The absorbance of the mixture was measured at 520 nm, and the scavenging activity of the testing solution was calculated as a percentage of radical reduction using the equation below. Each reaction was done in triplicate, and the values were averaged. The half-maximal effective concentration (EC_{50}) was incorporated from a graph plotted between the percentages of scavenging activity and their concentrations.

$$\%\ \text{Scavenging activity} = \frac{(A_{control} - A_{sample})}{A_{control}} \times 100$$

where $A_{control}$ is the absorbance of the control (without the extract) solution and A_{sample} is the absorbance of the testing solution.

ABTS radical scavenging assay

ABTS radical scavenging assay with some modifications by Hansakul et al [17] was also performed. The basis of this assay is the interaction between an antioxidant and the pre-generated ABTS radical cation. The 7 mM of ABTS solution was reacted with 2.45 mM of potassium persulfate (1:1) and then let stand for 12–16 h at room temperature in the dark to obtain the ABTS radical. The 20 µl of the tested extract

(15, 30, 60, 120, and 240 μg/ml) was reacted with 180 μl of the ABTS radical solution and then stirred for 6 min at ambient temperature in the dark. Trolox was used as a positive control. Absorbance of the testing solution was measured at 734 nm. Each reaction was done in triplicate, and the values were averaged. The scavenging activity of the testing solution was calculated as the percentages of radical reduction using the same equation as described in DPPH radical scavenging assay. The EC_{50} was obtained from a graph plotted as similar to DPPH assay.

Cell viability assay

The cell viability was performed on a mouse macrophage cell line (RAW 264.7) obtained from Department of Applied Thai Traditional Medicine, Faculty of Medicine, Thammasat University. RAW 264.7 macrophages were cultured in MEM supplemented with 2% bovine serum.

RAW 264.7 macrophages (1×10^5 cells/ml) were incubated with various concentrations of *B. ciliata* extract (31–500 μg/ml) at 37 °C with 5% CO_2 in a humidified incubator for 24 h. After completion of incubation period, 0.5 mg/ml of 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) solution was added and incubated for 4 h at 37 °C with 5% CO_2 in humidified incubator. The mixture solution was removed, and then the formazan products were dissolved with 0.04 M of HCl in isopropanol. The viability cells were analyzed by measuring the absorbance at 570 nm and then calculated using the equation below.

$$\% \text{ Cell viability} = \frac{A_{sample}}{A_{control}} \times 100$$

where $A_{control}$ is the absorbance of the control (without the extract) solution and A_{sample} is the absorbance of the testing solution.

The subtoxic concentration of the extract was interpolated from a graph plotted between percentages of viable cells to concentration. A concentration of the testing sample presented more than 80% of the vital cells was used for studying the nitric oxide radical scavenging activity.

Nitric oxide radical scavenging assay

Nitric oxide scavenging assay was carried out according to the previous experiment [17]. The RAW 264.7 macrophages (1×10^5 cells/ml) were incubated with various concentrations of *B. ciliata* extract (31, 62, 125, 250, and 500 μg/ml) at 37 °C with 5% CO_2 in a humidified incubator for 24 h. Then, incubated cells were further incubated with or without 5 μg/ml of lipopolysaccharide (LPS) at 37 °C with 5% CO_2 for 48 h. The supernatant was removed. The plate was added with 1.2 ml of Griess solution and then measured spectrophotometrically at 570 nm. Each reaction was done in triplicate, and the values were averaged. The cellular antioxidant activity, NO scavenging, was calculated as the percentages of NO scavenging activity using the equation below. The half-maximal inhibitory concentration (IC_{50}) was incorporated from a graph plotted between the percentages of scavenging activity and their concentrations.

$$\% \text{ Scavenging activity} = \frac{(A_{control} - A_{sample})}{A_{control}} \times 100$$

where $A_{control}$ is the absorbance of the LPS solution without the extract and A_{sample} is the absorbance of the testing solution.

Evaluation of α-glucosidase inhibition

The extracts of *B. ciliata* were determined for their α-glucosidase inhibitory activity, following the experiment by Elya et al [18] with some modifications. Ten μl of the testing solution (25, 50, 100, and 200 μg/ml) was thoroughly mixed with 490 μl of phosphate buffer pH 6.8 and 250 μl of 5 mM *p*-nitrophenyl α-D-glucopyranoside (*p*-NPG). The mixture was incubated at 37 °C with 5% CO_2 for 5 min. After that, the 250 μl of 1% α-glucosidase solution (0.15 U/ml, *Saccharomyces cerevisiae*, Sigma-Aldrich) was added and then incubated at 37 °C with 5% CO_2 for 15 min. Then, 2 ml of 200 mM sodium carbonate was added and stirred. Acarbose was used as a positive control. The α-glucosidase activity was analyzed by measuring absorbance at 400 nm. The inhibitory activity was determined as a percentage in comparison to a blank following the equation below. The IC_{50} was plotted from the linearity graph between the percentages of α-glucosidase inhibitory activity and its concentration.

$$\% \text{ Inhibition} = \frac{(A_{control} - A_{sample})}{A_{control}} \times 100$$

where $A_{control}$ is the absorbance of the *p*-NPG solution (enzyme+*p*-NPG) without the extract and A_{sample} is the absorbance of the testing solution.

Statistical analysis

The data in triplicate were analyzed and presented as the mean ± SD. Student's *t*-test was used to determine the significance between the test sample and the control at a 95% confidence level.

RESULTS

The whole parts of *B. ciliata* were sequentially extracted with an orderly increasing polarity of different solvents to obtain the crude extracts of hexane (BCH), dichloromethane (BCD), ethyl acetate (BCE), and methanol (BCM). The percent yield of the four extracts was 8.02, 0.97, 0.78, and 0.52, respectively.

Table 1 Phytochemical screening of *B. ciliata* extracts.

Constituent	Test	BCH	BCD	BCE	BCM
Alkaloid	Dragendorff's reagent	–	–	–	–
	Marquis's reagent	–	–	–	–
Flavonoid	Shinoda	–	+	++	++
	Pew's test	–	+	+	+
Saponin	Foam test	–	–	–	–
Tannin	Gelatine	–	–	–	–
	Lead acetate	–	–	–	–
Coumarin	Sodium hydroxide	–	–	–	–
Anthraquinone	Borntrager's	–	–	–	–
	Modified Brontrager	–	–	–	–
Cardiac glycoside	Raymond	–	–	–	–
	Keller-Kiliani	–	–	–	–
Cyanogenic glycoside	Sodium picrate	–	–	–	–

– absence; + moderate presence; ++ high presence.

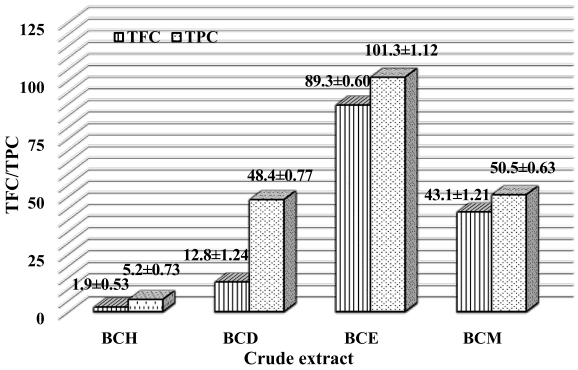

Fig. 1 Total phenolic content (mg GAE/g) and total flavonoid content (mg QE/g) of *B. ciliata* extracts with different solvents: hexane (BCH), dichloromethane (BCD), ethyl acetate (BCE), and methanol (BCM).

Phytochemical screening

In the study, four extracts were screened to identify the presence of phyto-constituents including tannins, saponins, coumarins, flavonoids, alkaloids, anthraquinones, cardiac glycosides, and cyanogenic glycosides. The results showed that BCM, BCE, and BCD were positive for Shinoda and Pew's test which were the screening test for flavonoids (Table 1).

Total phenolic content

TPC of four extracts was determined by measuring Folin-Ciocalteu reaction. Their quantities were derived from a calibration curve ($y = 0.003x + 0.0096$, $R^2 = 0.9998$) of gallic acid. The phenolic content was expressed as gallic acid equivalent in milligram per gram of dried crude extract (mg GAE/g). In this study, BCE (101.27 ± 1.12 mg GAE/g) showed the highest amount of phenolics. BCD and BCM had slightly different contents of phenolics which were 48.42 ± 0.77 and 50.52 ± 0.63 mg GAE/g, respectively, while BCH (5.2 ± 0.73 mg GAE/g) displayed the lowest of phenolic content (Fig. 1).

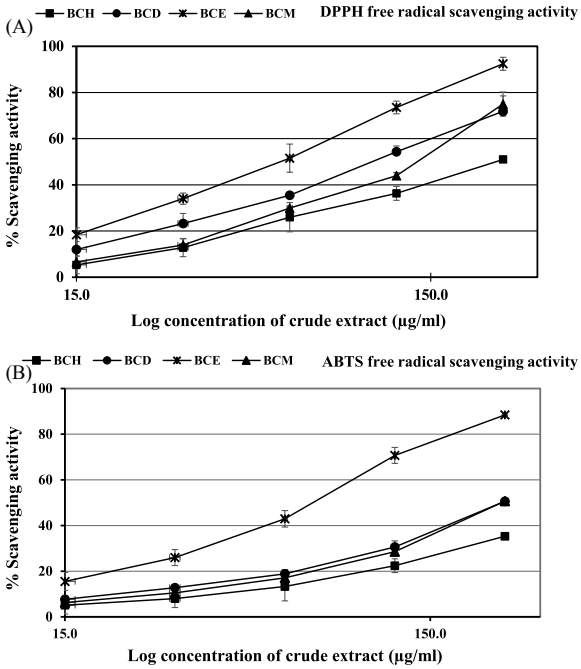

Fig. 2 Plots for antioxidant activity. (A) DPPH free radical scavenging activity and (B) ABTS free radical scavenging activity. The values are the mean ± SD ($n = 3$).

Total flavonoid content

TFC of four extracts were analyzed by using aluminium chloride reaction and derived from a calibration curve ($y = 0.0015x + 0.0021$, $R^2 = 0.9999$) of quercetin. Their flavonoid content was expressed as quercetin equivalent in milligram per gram of dried crude extract (mg QE/g). In the study, BCE (89.27 ± 0.60 mg QE/g) showed the highest amount of flavonoid content, followed by BCM (43.12 ± 1.21 mg QE/g), BCD (12.82 ± 1.24 mg QE/g) and BDH (1.93 ± 0.53 mg QE/g) (Fig. 1).

DPPH and ABTS radical scavenging activities

DPPH, a stable free radical, and ABTS, a cation free radical, have been widely used to assess the scavenging activities. In this study, BCE presented a good scavenging activity of DPPH radical with the IC_{50} value of 80.02 ± 4.34 µg/ml, whereas BCM and BCD showed moderate scavenging effect with IC_{50} values of 147.83 ± 3.41 and 135.04 ± 2.47 µg/ml, respectively (Table 2 and Fig. 2). The IC_{50} value for BHT, a positive compound, was 13.36 ± 0.18 µg/ml (Fig. 2). For the scavenging activity of ABST radical, BCE also possessed potent scavenging activity of the cation radical with the IC_{50} value of 97.07 ± 1.52 µg/ml, whereas BCM and BCD showed almost equally radical scavenging activity with IC_{50} values of 234.33 ± 2.92 and

Table 2 The scavenging activities of *B. ciliata* extracts against DPPH, ABTS, and NO radicals, expressed as the EC_{50} and the IC_{50}.

Crude extract	EC_{50} (μg/ml)		IC_{50} (μg/ml)	
	DPPH scavenging	ABST scavenging	NO scavenging	80% of vital cell
BCH	217.11 ± 3.55*	240*	207.11 ± 2.89	500
BCD	135.04 ± 2.47*	232.11 ± 1.20*	121.65 ± 3.48	500
BCE	80.02 ± 4.34*	97.07 ± 1.52*	194.16 ± 2.03	500
BCM	147.83 ± 3.41*	234.33 ± 2.92*	292.26 ± 3.17	500
BHT	13.36 ± 0.18			
Trolox		4.71 ± 0.04		

The values are the mean ± SD. * $p < 0.05$ represent significant difference between the testing sample and the positive control.

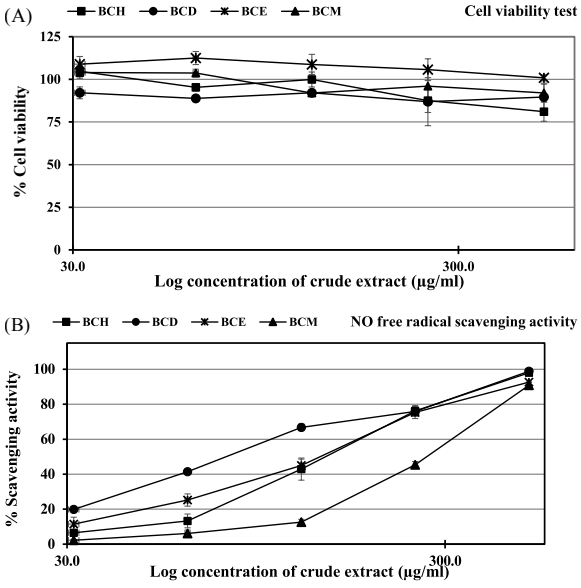

Fig. 3 Plots for intracellular antioxidant activity of four extracts. (A) Cell viability test and (B) NO free radical scavenging activity. The values are the mean ± SD ($n = 3$).

232.11 ± 1.20 μg/ml, respectively. Trolox, a positive compound, had an IC_{50} value of 4.71 ± 0.04 μg/ml. In this study, BCH exhibited the least inhibitory activity for both DPPH and ABST radicals.

Cellular antioxidant activity

NO radical was represented as cellular oxidant which was performed by using RAW 264.7 macrophages. The cytotoxic and the subtoxic concentrations (more than 80% of cell viability) of the four extracts form *B. ciliata* were used to evaluate the cellular antioxidant action. Each of the four extracts with the concentration of 31–500 μg/ml presented the survival cells with more than 80% (Fig. 3). In the test, BCD showed more potent NO scavenging activity than BCE. The IC_{50} value of BCD was 121.65 ± 3.48 μg/ml, whereas that of BCE was 194.16 ± 2.03 μg/ml. Meanwhile, BCM and BCH exhibited less scavenging activity (Table 2).

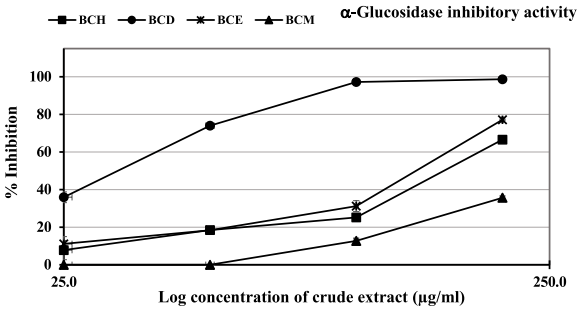

Fig. 4 Relationship between the percentage of α-glucosidase inhibition activity and the concentration of four extracts. The values are the mean ± SD ($n = 4$).

Table 3 The α-glucosidase inhibitory activities of four *B. ciliata* extracts, expressed as the IC_{50}. The values are the mean ± SD.

Crude extract	IC_{50} (μg/ml)
	α-glucosidase inhibition
BCH	169.92 ± 1.91
BCD	33.28 ± 1.36
BCE	145.89 ± 7.59
BCM	>200
Acarbose	370.13 ± 1.04

α-Glucosidase inhibitory activity

Four extracts were evaluated for their possible α-glucosidase inhibitory potential by using disaccharide hydrolysis *p*-NPG as a substrate. The results showed that three crude extracts from *B. ciliata* exhibited α-glucosidase inhibitory activity (Fig. 4). BCD exhibited the highest inhibitory activity with almost 100% inhibition (IC_{50} 33.28 ± 1.36 μg/ml). Meanwhile, BCE showed the inhibitory activity with the IC_{50} value of 145.89 ± 7.59 36 μg/ml, followed by BCH (IC_{50} 169.92 ± 1.91 μg/ml). BCM was the least active with the IC_{50} value of >200 μg/ml (Table 3).

DISCUSSION

B. ciliata, Commelinaceae family, is an abundant perennial herb for groundcover and rooftop greenery in topical areas of Asia. It is a succulent herb with the purple and pink color of capitulum which plays an interesting key role in exhibiting pharmacological activities. Even though the plant has not been scientifically reported, it is utilized in case of diabetic nephropathy treatment [13].

TPC and TFC were determined using the Folin-Ciocalteu assay and the aluminium chloride colorimetric method, respectively. BCE had the highest

amount of total phenolic and total flavonoid contents. Compounds presented in the plant extracted with different polarity solvents exhibited a distinct biological action. Naturally occurring plant antioxidants, the phenolic compounds — polar molecules, were found to possess strong antioxidant activities [19, 20]. The antioxidant capacity, the direct scavenge activity, of the extracts was evaluated using DPPH radical scavenging and ABTS radical scavenging assays. Both methods describe the ability of redox molecules in testing compounds to scavenge free radicals. This concept provides a framework of the antioxidants present in the biological compounds as it is considered the additive effects of all antioxidants rather than the effect of a single compound, and therefore being useful to study the potential health benefits of antioxidants on oxidative stress-mediated diseases [21]. In specification, the DPPH assay is based on the reduction of the purple $DPPH^{\cdot}$ to 1,1-diphenyl-2-picryl hydrazine, whereas the ABTS assay is based on the generation of a blue/green $ABTS^{\cdot+}$ that can be reduced by antioxidants. The ability of BCE to scavenge DPPH and ABTS free radicals was found to be more than 80%, which was the highest scavenging activity. The EC_{50} value was observed to be 80.02 ± 4.34 μg/ml for DPPH and 97.07 ± 1.52 μg/ml for ABTS. However, these scavenging effects for DPPH and ABTS were lower than those of the positive control, BHT and Trolox, due to the large components in the crude extract. Based on its constituents, the antioxidant activities of DPPH and ABTS free radicals of *B. ciliata* may be from the presence of phenolic compounds especially flavonoids. The phytochemical screening confirmed that its constituents contain a molecule of 2-phenyl-γ-benzopyrone which is a basic skeleton of flavonoid. This result is correlated with a previous report in that the predominant constituents in Commelinaceae family are C-glycosylflavones (in 78% of species) with flavonol glycosides, mainly quercetin, tricin, 6-hydroxyluteolin, sulphated flavones, and anthocyanins are found in the leaves and petals [22]. Based on free radical scavenging activity, these molecules readily donated hydrogen atom to the free radicals.

An inflammatory mediator, NO, can be produced from various inflammatory cells especially macrophages. NO plays an important role in the promotion and prolongation of the cellular inflammation [23]. Obviously, data indicated that the active compounds from the plant which diminish NO production, especially with corresponding low cytotoxicity and low active concentration, could be used to suppress the inflammatory response by NO [24]. From the current study, NO was released from LPS-treated RAW 264.7 macrophages which represented the cellular oxidative molecules. All *B. ciliata* extracts significantly exhibited NO scavenging activity which was found to be more than 80% inhibition. BCD had more potential scavenger for NO free radical than the others with the IC_{50} value of 121.65 ± 3.48 μg/ml. NO is a small free radical molecule, which easily accepts an electron from other molecules. Another mechanism of scavenging activity involved the lipophilicity of the constituents of *B. ciliata* extracts influencing their inhibitory activity due to "like dissolves like" as they could penetrate through biological barriers [25].

The α-glucosidase is one of the main enzymes in human that is responsible for the breakdown of the glycosidic bonds of carbohydrates to obtain a small molecule which leads to a high blood glucose level after meal. As the results, only BCD showed an excellent activity of almost 100% for α-glucosidase inhibition. Its IC_{50} value was observed to be 33.28 ± 1.36 μg/ml. In previous reports, flavonoids are the largest group of phenolic compounds obtained from the plants in Commelinaceae family exhibiting various pharmacological activities such as anti-inflammatory [26], anticancer [27], neuroprotective [28], antiviral [29], and antibacterial [30] activities. The α-glucosidase inhibitory activity of *B. ciliata* extract for treatment of diabetes mellitus has not been reported. This study proved that *B. ciliata* exhibited a strong α-glucosidase inhibition. However, it was not related to the phenolic and flavonoid constituents.

CONCLUSION

B. ciliata extracts possessed both antioxidant activity and α-glucosidase inhibitory potential. Ethyl acetate extract showed the highest scavenging activity for DPPH and ABTS radicals. Their antioxidant activity was due to phenolic and flavonoid contents, which were abundant. Besides, dichloromethane extract exhibited NO scavenging and α-glucosidase inhibitory activities. The amount of phenolic and flavonoid contents was less influential in these activities due to the property of cell membrane permeability. However, the chemical structure of phytochemical compounds from *B. ciliata* should be further elucidated for their activities, and *in vivo* studies may be carried out to support the findings of the current study.

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