Original Article

Inhibitory Effect on Alpha-glucosidase Activity of Benjakul, Soros Benjakul and Their Plant Components

Pornthep Temrangsee*, Arunporn Itharat**, ***,
Chisanucha Sattaponpan****, Weerachai Pipatrattanaseree*****

Abstract

Introduction: Acarbose as α-glucosidase inhibitor reduces blood sugar level and are used to treat diabetes. Thai traditional medicine considered it as an imbalance of body functions. Benjakul (B) and Soros Benjakul (SB) are formulas used for correcting the imbalance. This study reported α-glucosidase inhibition of these formulas.

Method: B and SB comprised 5 plants in different ratios. These were: fruit of *Piper retrofractum* Linn. (PR), root of *Piper sarmentosum* Roxb. (PS), stem of *Piper interruptum* Opiz. (PI), root of *Plumbago indica* Linn. (PL) and rhizome of *Zingiber officinale* Rosc. (ZO). Each plant and plant mixtures (B and SB1-SB5) were extracted by three different methods; 1) maceration, 2) decoction, and 3) digestion. The α-glucosidase inhibitory activity was performed and the content of piperine was analysed.

Results: The ethanolic extract and the digested extracts of PI gave IC_{50} of 132.30 µg/ml and 151.35 µg/ml. Piperine showed IC_{50} of 45.26 µg/ml. The IC_{50} of acarbose was 142.77 µg/ml. SB2-SB4 after digestion showed improved activities.

Discussion: Piperine had strongest activity as α-glucosidase inhibitor and the content was highest in PI which explained higher activity of this plant. The digested extracts showed improvement of activities, especially SB2 and SB3.

Conclusion: Piperine and the ethanolic extracted of PI was more active than acarbose as α-glucosidase inhibitor. B and SB exerted moderate to good activity. The SB for diabetics should be the formula for water (SB2) or wind (SB3) elements.

Keywords: Benjakul, Soros Benjakul, Alpha-glucosidase, Diabetes mellitus, piperine

Received: 25 June 2019 **Revised: 5 July 2019** **Accepted: 8 July 2019**

* Student of Doctor of Philosophy (Medical Sciences), Faculty of Medicine, Thammasat University
** Department of Applied Thai Traditional Medicine, Faculty of Medicine, Thammasat University
*** Center of Excellence on Applied Thai Traditional Medicine Research (CEATMR), Faculty of Medicine, Thammasat University
**** Research Administrative Office, Faculty of Medicine, Thammasat University
***** Regional Medical Science Center 12 Songkhla, Department of Medical Sciences, Ministry of Public Health
Corresponding author: Associate Professor Dr. ArunpornItharat, Department of Applied Thai Traditional Medicine, Faculty of Medicine, Thammasat University and Center of Excellence on Applied Thai Traditional Medicine Research (CEATMR), Faculty of Medicine, Thammasat University, E-mail: iarunporn@yahoo.com

Introduction

Diabetes mellitus (DM) is a chronic metabolic disease characterizing by high levels of blood glucose. There are three types of diabetes. Diabetes type 1 caused by body's failure to produce enough insulin. This formerly called "Insulin-dependent diabetes" or "diabetes, puberty" the cause is still unknown. DM type 2 begins with insulin resistance, a condition in which the cells do not respond to insulin properly. DM during pregnancy is the third type. The high blood sugar is detected in the woman who was pregnant without history of diabetes. Diabetes is a major cause of blindness, kidney failure, heart attacks, stroke and lower limb amputation. In 2016, an estimated 1.6 million deaths were directly caused by diabetes.[1] According to WHO's guideline, Metformin was commonly recommended to treat diabetes type 2, because it could reduce the death rate.[2]

The α-glucosidase is a membrane-bound enzyme located on the epithelium of the small intestine, it catalyzes the cleavage of disaccharides yielding glucose. The inhibitors of this enzyme could retard the uptake of dietary carbohydrates and suppress post-prandial hyperglycemia. Therefore, inhibition of α-glucosidase could be an effective approach to control diabetes.[3, 4, 5] At present modern medicine utilize acarbose whose action is α-glucosidase inhibition, however, some patients experienced side effects such as diarrhea and flatulence from this medication.

Thai traditional medicine (TTM) recognize diabetes as one of degenerative diseases resulted from an imbalance of physiological functions of body or Dhatu imbalance. There are some herbal formulas to correct these imbalances i.e. Benjakul (B) Soros Benjakul (SB).[6]

B and SB had been used for health promotion and also used as an adaptive drug in The National Drug List of Herbal Medicine Products A.D. 2006.[7] These remedies focus on the four elements (Dhatu) of the body (earth, water, wind and fire) including the free space (akash) TTM.[8, 9, 10] If the four elements (earth, water, wind and fire) and akash are in balance, it would lead to good health. On the other hand, if the body has any of the four elements out of balance, the body will be in ill-health. The B and SB remedies comprise five medicinal plants, each of which is a drug of choice for nourishing the four elements and akash in the body.[10] The ratio of five plants in SB formulas were set according to pathology of the patient whether major illness resulted from either one of the five dhatus.

The objective of this study was to determine the α-glucosidase inhibitory activity of B remedy, five formulas of SB remedies, each plant component and piperine.

Materials and methods

Raw materials

The fruits of *Piper retrofractum* Linn. (PR), the root of *Piper sarmentosum* Roxb. (PS), the stem of *Piper interruptum* Opiz. (PI), the root of *Plumbago indica* Linn. (PL) and the rhizome of *Zingiber officinale* Rosc (ZO). were bought from various provinces in Thailand. The identity of the plant materials and voucher numbers were verified by 1) BKF - Bangkok Forest Herbarium, Herbarium Department of National Parks, Wildlife and Plant Conservation, Bangkok, Thailand, and 2) SKP - Southern Center of Thai Medicinal Plants at Faculty of Pharmaceutical Science, Prince of Songkhla University Songkhla, Thailand (Table 1). The proportions of the herbs in these remedies were shown in Table 2.

Table 1 The general data of plant materials of B and SB remedies.

Botanical name	Thai name	Part of used	Source	Voucher number of specimens
Piper retrofractum Linn.	Dee-Pli	Fruit	Ratchaburi	BKF 192296 / SKP 146160301
Piper sarmentosum Roxb.	Cha-Plu	Root	Ratchaburi	BKF 192197 / SKP 146161901
Piper interruptum Opiz.	Sa-Khan	Stem	Chiang Mai	BKF 192199
Plumbago indica Linn.	Chettamun phloengdaeng	Root	Bangkok	BKF 192195 / SKP 148160901
Zingiber officinale Rosc.	Khing	Rhizome	Ratchaburi	BKF 192198 / SKP 206261501

Table 2 The ratio of herbal plants of B and SB remedies

Remedies		Ratio of herbal plants				
		PR	PS	PI	PL	ZO
Benjakul(B)		1	1	1	1	1
Soros Benjakul (SB)						
SB for earth element	SB1	16	8	6	4	2
SB for water element	SB2	2	16	8	6	4
SB for wind element	SB3	4	2	16	8	6
SB for fire element	SB4	6	4	2	16	8
SB for akash element	SB5	8	6	4	2	16

Note: PR = Dee-pli (*Piper retrofractum* Linn.), PS = Cha-plu (*Piper sarmentosum* Roxb), PI = Sa-khan (*Piper interruptum* Opiz.), PS = Chettamunphloengdaeng (*Plumbago indica* Linn.), and ZO = Khing (*Zingiber officinale* Rosc.)

Extraction of plants

The plant materials were mixed well according to the proportions of B and SB remedies (Table 2). The mixed materials were extracted by three methods; 1) maceration with 95% ethanol (E), 2) decoction with water (W), and 3) digestion by boiling with 0.1N HCl pH 2 (simulating gastric condition) (H). The digested product was extracted with chloroform and evaporated to dryness.

Inhibitory effect on α-glucosidase activity

The α-glucosidase inhibitory activity was modified from established methods.[11, 12] In brief, five concentrations (100, 200, 400, 800 and 1000 µg/ml) of the sample and five concentrations (25, 50, 100, 200, 400, 800 and 1000 µg/ml) of piperine were prepared. A 20 µl of the test sample in DMSO/water, 80 µl of 100 mM phosphate buffer (pH 6.8), and 50 µl of substrate (5 mM p-nitrophenyl α-D-glucopyranoside (p-NPG), in

phosphate buffer) were added to 96-well plate and pre-incubated at 37 °C for 5 minutes. Then a 50 µl of α-glucosidase was added and incubated at 37 °C for 15 minutes. The reaction was ceased by adding 100 µl of 1M sodium carbonate (Na_2CO_3). The release of p-nitrophenol was measured at 405 nm by a micro-plate reader (Biotek, USA). All tests were performed in triplicate. The percentage of enzyme inhibition was calculated by [($Abs_{control}$ - Abs_{sample})/Abscontrol] x 100, Abs is Absorbance /Optical density (OD). The IC_{50} values were calculated using Prism program.

Determination of content of the chemical markers

Marker compounds of B and SB were determined according to Itharat and Sakpakdeejaroen (2010)[13] method by using a High Performance Liquid Chromatography (HPLC) system, (Agilent Technologies®, USA). A reversed-phase column was ZORBAX Eclipse XDB-C18 (4.6 x 250 mm, 5 µm). The mobile phase composed of 65% water : 35% acetonitrile with gradient elution as follows: 0 - 30 minute, 65:35; 31-50 minute, 50:50; 51 - 65 minute, 5:95. The flow rate was 1 ml/min, the injected volume was 20 µL. The detector was set at 210 nm and 256 nm.

Statistical analysis

All data were expressed as mean ± standard error of the mean (SEM). One-way ANOVA was used to compare the statistical differences between sample groups and positive control (P - value < 0.05).

Results

Inhibitory effect on α-glucosidase enzyme activity

Inhibition of α-glucosidase enzymatic activity of B, SB, their plant components and piperine were investigated (Table 3). The ethanolic and digested extracts of PI showed the highest α-glucosidase inhibitory activity with IC_{50} value of 132.30 ± 1.48 µg/ml and 151.35 ± 3.54 µg/ml, respectively. Their potencies were comparable to that of acarbose (IC_{50} = 142.77 ± 1.05 µg/ml). The ethanolic and digested extracts of PR also inhibited the α-glucosidase activity with IC_{50} values of 387.72 ± 3.14 µg/ml and 241.02 ± 0.60 µg/ml, respectively. All water extracts showed little activity as α-glucosidase enzyme inhibitors with IC_{50} more than 1000 µg/ml.

Table 3 The IC_{50} values of α-glucosidase inhibitory activity of Benjakul remedy, Soros Benjakul remedies, and their plant components.

Sample	Code	IC_{50} of α-glucosidase (μg/ml)(Mean ± SEM)		
		W	E	H
Piper retrofractum Linn.	PR	>1000*	387.72 ± 3.15*	241.02 ± 0.60*
Piper sarmentosum Roxb.	PS	>1000*	948.79 ± 3.56*	>1000*
Piper interruptum Opiz.	PI	>1000*	132.30 ± 1.48	151.35 ± 3.54
Plumbagoindica Linn.	PL	>1000*	728.19 ± 3.92*	625.92 ± 3.57*
Zingiber officinale Rosc.	ZO	>1000*	>1000*	>1000*
Benjakul remedy	B	>1000*	782.48 ± 3.52*	729.15 ± 2.36*
Earth element	SB 1	>1000*	430.46 ± 3.25*	647.14 ± 3.49*
Water element	SB 2	>1000*	>1000*	388.46 ± 3.87*
Wind element	SB 3	>1000*	699.98 ± 2.55*	193.99 ± 3.33*
Fire element	SB 4	>1000*	769.32 ± 3.21*	729.11 ± 1.93*
Akash element	SB 5	>1000*	>1000*	>1000*
Acarbose (positive control)		142.77 ± 1.05 [0.21 mM]		

* The mean difference is significant at the 0.05 level (comparison with positive control)

The ethanolic extracts of B and SB exhibited moderate inhibitory effect on α-glucosidase enzyme with IC_{50} values in the range of 400 - 800 μg/ml. However, the digested extracts showed more potent activity than its ethanolic extract, especially SB3 showed the highest inhibitory activity with IC_{50} of 193.99 ± 3.33 μg/ml.

Piperine showed the highest α-glucosidase inhibitory activity with IC_{50} of 45.26 ± 1.24 μg/ml [0.16 mM] which was higher than acarbose (Table 4). This is the first report for *in vitro* study of piperine. Other chemical constituents in B and SB such as shogaol, gingerol (two ingredients in ZO) and plumbagin (ingredient in PL) showed moderate activity with IC_{50} more than 200 μg/ml.

Table 4. Inhibitory activity (IC_{50}) on α-glucosidase activity of pure compounds.

Sample	Inhibitory activity (Mean ± SEM) (μg/ml) [mM]
Piperine	45.26 ± 1.24* [0.16 mM]
Shogaol	255.44 ± 4.03* [0.92 mM]
Gingerol	334.10 ± 3.85* [1.14 mM]
Plumbagin	204.31 ± 1.74* [1.09 mM]
Acarbose (positive control)	142.77 ± 1.05 [0.21 mM]

* The mean difference is significant at the 0.05 level (comparison with positive control)

Content of chemical constituents of B, SB and their plant components

The content of pure compounds constituted in B and SB were analyzed by previous study using an HPLC method.[13] Table 5 shows the content of major active ingredients in ethanolic and digested extracts extract of B, SB and their plant components. All digested extracts showed much less content of marker compounds than the ethanolic extracts except that of plumbagin. The highest content of piperine was found in ethanolic extract of PI (166.30 ± 15.34 mg/g) and the ethanolic extract of SB and B, respectively. Piperine content in most of these extracts was more than 100 mg/g except PR and PS and was the main compound in all these extracts.

Table 5 The chemical contents of Benjakul (B) remedy, Soros Benjakul (SB) remedies, and their plant components.

Sample	Extract	Concentration (mg/g)			
		Gingerol	Plumbagin	Piperine	Shogaol
P. retrofractum (PR)	E	-	-	95.14 ± 2.11	-
	H	-	-	6.02 ± 0.13	-
P. interruptum (PI)	E	-	-	166.30 ± 15.34	-
	H	-	-	10.30 ± 0.08	-
P. sarmentosum (PS)	E	-	-	23.10 ± 3.28	-
	H	-			
P. indica (PL)	E	-	0.55 ± 0.17	-	-
	H	-	4.33 ± 0.05	-	-
Z. officinale (ZO)	E	33.58 ± 0.90	-	-	38.27 ± 2.91
	H	5.19 ± 1.27	-	-	0.82 ± 0.45
B	E	8.78 ± 0.71	-	127.66 ± 16.24	12.23 ± 1.89
	H	1.93 ± 0.17	-	4.62 ± 0.35	1.68 ± 1.51
SB 1	E	1.73 ± 0.05	-	175.72 ± 1.62	5.16 ± 0.40
	H	0.26 ± 0.05	-	4.08 ± 0.60	0.51 ± 0.07
SB 2	E	5.82 ± 0.09	-	102.31 ± 8.89	8.88 ± 0.17
	H	0.43 ± 0.07	-	3.53 ± 0.02	0.71 ± 0.07
SB 3	E	7.68 ± 0.14	0.04 ± 0.001	127.66 ± 1.62	10.26 ± 0.35
	H	1.28 ± 0.07	0.48 ± 0.05	4.42 ± 0.01	0.20 ± 0.02
SB 4	E	11.13 ± 0.19	0.07 ± 0.002	123.76 ± 1.88	11.47 ± 0.05
	H	2.20 ± 0.12	0.59 ± 0.01	4.50 ± 0.03	0.59 ± 0.04
SB 5	E	13.20 ± 0.17	-	112.03 ± 2.38	14.33 ± 0.16
	H	2.70 ± 0.20	-	4.45 ± 0.09	1.08 ± 0.15

Note: H = digested extract, E = Ethanolic extract

Discussion and Conclusion

Piperine was a major component in HPLC fingerprint of B in previous report of Rattarom *et al*.[14] Piperine was also tested for antidiabetic effect in vivo with positive result.[15] These results demonstrated that piperine was the active component that could be used as a marker of B for α-glucosidase inhibitor. Although, piperine was one of the major components in B and SB determined by HPLC with high content similar to PI, however, the inhibitory results of B and SB were not better than PI. These may due to other components in B and SB extract. However, the digested extract of SB exhibited improved inhibitory activity except SB1.

The fact that piperine content was much reduced in the digested extracts, this could be due to the formation of hydrochloride salts which were insoluble in chloroform. This transformation would explain the remaining of α-glucosidase inhibitory activity in these extracts. Moreover the activity of the digested extract was higher than the ethanolic extract.

The ethanolic extracts of PR, PS, PL and ZO showed moderate activity related to quantity of their responsible compounds. The content of piperine in PI was more than PR and PS, therefore PI exhibited inhibitory activity better than PR and PS.

This is the first report of B, SB, their digested extracts, piperine and PI on α-glucosidase inhibitory activity.

Piperine exhibited potent inhibitory activity against α-glucosidase enzyme comparing with acarbose. The ethanolic and digested extracts of PI also showed comparable inhibitory activity. The SB formula for the water element (SB2) and the wind element (SB3) are appropriate to be used with diabetic patients due to higher activities as α-glucosidase inhibitors after digestion.

Acknowledgements

The author wishes to acknowledge the Center of Excellence in Applied Thai Traditional Medicine and Faculty of Medicine, Thammasat University for financially support and laboratory facilities.

References

1. World Health Organization (WHO). Global report on diabetes.France; 2016. (https://www.who.int access on 18 June 2019).
2. Ripsin C M, Kang H, Urban R J. Management of blood glucose in type 2 diabetes mellitus. Am Fam Physician. 2009;79(1):29–36.
3. Guilin C, Mingquan G. Rapid Screening for α-Glucosidase Inhibitors from Gymnemasylvestre by Affinity Ultrafiltration-HPLC-MS. Front Pharmacol. 2017;8(228):1-8.
4. Toshiro M, Chiho Y, Katsuhiro O, Tomoyuki O, Yutaka O. In Vitro Survey of α-Glucosidase Inhibitory Food Components, Biosci Biotech Biochem. 1996;60(12):2019-22.
5. Sheikh-Ali M, Karon B, Basu A, Kudva Y, Muller L, Xu J, Schwenk WF, Miles J M. Can serum B-hydroxybutyrate be used to diagnose diabetic ketoacidosis? Diabetes Care. 2008;31(4):643-7.
6. Kritsadee S. Diabetes mellitus (madhumeho) in Thai Traditional Medicine theory. Proceedings of Academics World 52nd International Conference. 2016 Nov 21 - 22; Los Angeles, USA.
7. Bureau of Drug Control. The National Drug List of Herbal Medicine Products A.D. 2006. Bangkok, Thailand; 2012.
8. Itharat A, Singchangchai P, Rattanasuwan P. Folk wisdom of traditional doctors in south of Thailand. Songklanakarin J Sci Technol. 1999;24:126-7.

9. Tappayuthpiijarn P, Itharat A, Sakpakdeejaroen I, pawa KK. Cytotoxic activity of the traditional Thai medicinal plant preparation Benjakul and 4 isolated compounds. Planta Med. 2007;73:589.
10. Sriyakul K, Kietinun S, Itharat A, Pattaraarchachai J, Kittipawong P, Sakpakdeejaroen I, Kamalashiran C, Sunopuk R, Chunthorng-orn J, Issarata T, Tonthong B, Chamnanaukson W, Chinsoi P. Preliminary comparative study on the efficacy and side effects of Benjakulin normal and imbalanced Dhatu volunteers. Applied Thai Traditional Medicine, Faculty of Medicine, Thammasat University, Thailand. 2010.
11. Kumar JA, Tiwari AK, Ali AZ, Madhusudhana K, Reddy BS, Ramakrishna S, China Raju B. New antihyperglycemic, α-glucosidase inhibitory and cytotoxic derivatives of benzimidazoles.J Enzyme Inhib Med Chem. 2010;25(1):80-6.
12. Gowri PM, Tiwari AK, Ali AZ, Rao JM. Inhibition of α-glucosidase and amylase by bartogenic acid isolated from Barringtonia racemose Roxb. seeds. Phytother Res. 2007;21(8):796-9.
13. Itharat A, Sakpakdeejaroen I. Determination of cytotoxic compounds of Thai traditional medicine called Benjakul using HPLC. J Med Assoc Thai.2010; 93 (Suppl.7): S198-S203.
14. Rattarom R, Sakpakdeejaroen I, Hansakul P, Itharat A. Cytotoxic Activity Against Small Cell Lung Cancer Cell Line and Chromatographic Fingerprinting of Six Isolated Compounds from the Ethanolic Extract of Benjakul. J Med Assoc Thai. 2014;97 (Suppl.8):S70-5.
15. Kumar S, Sharma S, Vasudeva N. Screening of antidiabetic and antihyperlipidemic potential of oil from Piper longum and piperine with their possible mechanism. Expert OpinPharmacother. 2013;14(13):1723-36.

บทคัดย่อ

ประสิทธิภาพของตำรับยาเบญจกูล โสฬสเบญจกูล สารสกัดจากพืชในตำรับรวมถึงสารบริสุทธิ์ในการยับยั้งเอนไซม์แอลฟ่ากลูโคสิเดส

พรเทพ เต็มรังษี*, อรุณพร อิฐรัตน์, ***, ชิษณุชา สัตพนพันธุ์****, วีระชัย พิพัฒน์รัตนเสรี*****

* นักศึกษาดุษฎีบัณฑิต (วิทยาศาสตร์การแพทย์) คณะแพทยศาสตร์ มหาวิทยาลัยธรรมศาสตร์

** สถานการแพทย์แผนไทยประยุกต์ คณะแพทยศาสตร์ มหาวิทยาลัยธรรมศาสตร์

*** ศูนย์ความเป็นเลิศทางการวิจัยแพทย์แผนไทยประยุกต์ คณะแพทยศาสตร์ มหาวิทยาลัยธรรมศาสตร์

**** งานบริหารการวิจัย คณะแพทยศาสตร์ มหาวิทยาลัยธรรมศาสตร์

***** ศูนย์วิทยาศาสตร์การแพทย์ที่ 12 สงขลา กรมวิทยาศาสตร์การแพทย์ กระทรวงสาธารณสุข

ผู้ให้ติดต่อ: รองศาสตราจารย์ ดร. อรุณพร อิฐรัตน์ สถานการแพทย์แผนไทยประยุกต์ คณะแพทยศาสตร์ มหาวิทยาลัยธรรมศาสตร์ และศูนย์ความเป็นเลิศทางการวิจัยแพทย์แผนไทยประยุกต์ คณะแพทยศาสตร์ มหาวิทยาลัยธรรมศาสตร์ อีเมล: iarunporn@yahoo.com

บทนำ: อะคาโบสเป็นยาใช้ยับยั้งเอนไซม์แอลฟ่ากลูโคซิเดสเพื่อลดระดับน้ำตาลในเลือดและใช้กับผู้ป่วยโรคเบาหวาน ในทางการแพทย์แผนไทยพิจารณาว่าโรคเบาหวานเกิดจากความไม่สมดุลในการทำงานของร่างกาย ตำรับยาเบญจกูลและโสฬสเบญจกูลเป็นสูตรยาที่ใช้ในการปรับสมดุลในร่างกาย ในการศึกษาครั้งนี้ มีจุดประสงค์เพื่อศึกษาฤทธิ์ในการยับยั้งเอนไซม์แอลฟ่ากลูโคซิเดสของตำรับยาสมุนไพรเหล่านี้

วัสดุและวิธีการ: เบญจกูลและโสฬสเบญจกูลประกอบด้วยพืชสมุนไพร 5 ชนิดที่มีอัตราส่วนแตกต่างกันประกอบด้วย ดอกดีปลี รากช้าพลู เถาสะค้าน รากเจตมูลเพลิง และเหง้าขิง แต่ละตำรับยาจะนำสมุนไพรเหล่านี้มารวมกันแล้วทำการสกัดด้วยวิธีที่แตกต่างกัน 3 วิธี 1) สกัดด้วยแอลกอฮอล์ 2) ต้มด้วยน้ำ และ 3) ย่อยด้วยกรดเข้าสู่กระบวนการทดสอบฤทธิ์การยับยั้งเอนไซม์แอลฟ่ากลูโคซิเดสและวิเคราะห์ปริมาณสารพิเพอรีน

ผลการศึกษา: สารสกัดเอทานอลและการย่อยของเถาสะค้าน มีค่า IC_{50} = 132.30 µg/ml, 151.35 µg/ml สารพิเพอรีนมีฤทธิ์ดีที่สุดมีค่า IC_{50} = 45.25 µg/ml ส่วนอะกาโบสมีค่า IC_{50} = 142.77 µg/ml สารสกัดสูตร SB2 - SB4 หลังจากทำการย่อยแล้วมีฤทธิ์ดีขึ้น

วิจารณ์ผล: สารพิเพอรีนมีฤทธิ์ยับยั้งเอนไซม์แอลฟ่ากลูโคซิเดสได้ดีที่สุดและมีอยู่มากที่สุดในสารสกัดเถาสะค้านซึ่งทำให้มีฤทธิ์ในการยับยั้งสูง สารสกัดด้วยวิธีการย่อยแสดงผลการยับยั้งได้ดีในสูตร SB2 และ SB3

สรุปผลการศึกษา: สารพิเพอรีนและสารสกัดเอทานอลของเถาสะค้านมีฤทธิ์ยับยั้งเอนไซม์แอลฟ่ากลูโคซิเดสดีกว่าอะกาโบส สารสกัดเบญจกูลและโสฬสเบญจกูลมีฤทธิ์ยับยั้งปานกลางจนถึงดี สูตรยาโสฬสเบญจกูลที่น่าจะนำมาใช้กับโรคเบาหวานคือสูตรสำหรับธาตุน้ำ (SB2) และสูตรสำหรับธาตุลม (SB3)

คำสำคัญ: เบญจกูล, โสฬสเบญจกูล, แอลฟ่ากลูโคซิเดส, เบาหวาน, พิเพอรีน