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BLOOD GLUCOSE LEVEL AND LIPID PROFILE OF ALLOXAN–INDUCED DIABETIC RATS TREATED WITH NA-ALGINATE FROM SEAWEED *Turbinaria ornata* (Turner) J.Agardh

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Graphical abstract
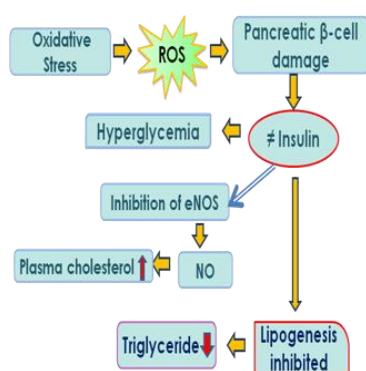
Abstract

Diabetes mellitus (DM) is a metabolic disorder due to insulin deficiency, insulin resistance or inability of β–cells of pancreas to produce insulin. This study was aimed to evaluate the effects of Na-alginate from *Turbinaria ornata* (Turner) J.Agardh on glucose level and lipid profile in alloxan–induced diabetic rats. Na-alginate was extracted from *T. ornata* then analyzed by TLC and FTIR. *In vivo* test was performed on alloxan monohydrate induced diabetic rats. *In vivo* parameters evaluated were body weight, blood glucose and lipid profiles (total cholesterol, HDL-c, LDL-c, and triglyceride). *In vivo* test was conducted by a complete randomized design with six treatments, 0.5 % CMC-Na, glibenclamide 5 mg kg^{-1}, Na-alginate 200 mg kg^{-1}, Na-alginate 400 mg kg^{-1}, Na-alginate 600 mg kg^{-1}, and NaCl 0.9 % per each five replications. The results showed that Na-alginate at 600 mg·kg^{-1} increased weight of rat significantly comparing to normal control. Na-alginate 600 mg kg^{-1} also lowered preprandial and postprandial glucose better than other doses. Increasing dose of Na-alginate lowered total cholesterol, increased HDL-c, and lowered LDL-c. The higher dose of alginate gave greater effect on diabetic rats. However, Na-alginate did not affect the triglyceride.

Keywords: Blood glucose, diabetes, lipid profiles, Na-alginate, seaweed

1.0 INTRODUCTION

Diabetes Mellitus (DM) is a disease caused by hyperglycemia due to relative or absolute insulin deficiency. Chronic hyperglycemia can lead to complications such as cardiovascular disease, retinopathy, nephropathy, and neuropathy [1]. Hyperglycemia can also lead to impaired balance metabolism of carbohydrates, fats, and proteins [2]. International Diabetes Federation (IDF) estimates that in 2013 there were 382 × 10^6 people with diabetes and 316 × 10^6 people suffer from impaired glucose tolerance and increased risk of diabetes. These results are expected to increase to 471 × 10^6 at 2 035 and predicted less than 25 yr there would be 592 × 10^6 people suffer from diabetes without quick and precise prevention [3].

Seaweeds contain polysaccharides, proteins, amino acids, lipids, peptides, minerals and some vitamins. Polyphenols of seaweed are used as cosmetics and pharmacologicalsas antioxidants, protection from radiation, antibiotics, anti–inflammatory, hypo–allergenic, antibacterial and antidiabetic [4]. Phenol extract of seaweed Palmaria,

Ascophyllum, Padina and Alaria able to inhibit the activity of α-amylase and α-glucosidase that can lower blood glucose levels [5, 6]. Beside that, seaweed also has a high content of antioxidants that can be used to ward off free radicals that increase due to the condition of hyperglycemia in patients with diabetes mellitus [7].

Research on the use of Na-alginate from *Turbinaria ornata* on inhibition of carbohydrate enzyme activity and *in vivo* studies in diabetic rats was limited. This study is expected to provide information on the effect of Na-alginate from *T. ornata* on the blood glucose and lipid profiles of alloxan–induced diabetic rats.

2.0 EXPERIMENTAL

2.1 Extraction of Na-alginate from *T. ornata*

Na-alginate was extracted by modification of Rashid method [8] on the solution concentration, the amount of solution, and the separation of the supernatant and filtrate. Dried samples were weighted and were soaked in distilled water with addition of 0.1 N HCl to pH 4 for about 24 h 1:15 (w/v). The seaweed was washed with distilled water until pH 7. The filtrate was added with 0.5 N Na_2CO_3 (pH 11) 1:10 (w/v) then heated at 60 °C for 2 h. The viscous mixture was added with distilled water 1:10 (w/v) and separated from its residue by centrifuge (3 500 rpm, 5 min, 4 °C) [1 rpm = 1/60 Hz]. The Na-alginate extract was added with 5 N H_2O_2 1:4 (v/v), stirred for 30 min before left for 2 h. The mixture was added with 0.5 M $CaCl_2$ and stirred for 30 min followed by adding 0.5 N HCl until pH 2. The mixtured was stirred and left for 30 min at room temperature. Insoluble material (alginic acid) was separated from the supernatant by centrifuge. Alginic acid was weighed and was added with distilled water and 0.5 N Na_2CO_3 2:2:3 (w/v/v), stirred for 1 h at room temperature to obtain solid form of Na-alginate. Na-alginate was precipitated with EtOH slowly 1:1 (v/v) and stirred for 30 min, thereafter centrifuged, followed by dried at 60 °C and the yield of alginate was determined.

2.2 Alginate Characterizations

Viscosity measurements for alginate samples carried out with Viscometer and water content were determined according to AOAC method [9]. Hydrolysis of alginate from *T. ornata* was performed using strong acid [10]. Sodium alginate used as standard was commercial polysaccharide alginate. The degraded products after acid treatments were analyzed by thin layer chromatographi (TLC). TLC was conducted on TLC silica gel plates (10 cm × 2.5 cm) using mobile phase composition of 1-propanol, ethyl acetate, and water 2:7:1 (v/v/v). Identification of polysaccharide structured was identified by FTIR–spectroscopy. A pellet of sodium alginate was prepared with KBr (kalium bromide). FTIR spectrum was recorded on Shimadzu–FTIR Prestige 21 with a resolution of 4 cm^{-1} in the 4 000 cm^{-1} to 400 cm^{-1} region, with scan speed of 0.20 cm s^{-1}.

2.3 *In Vivo* Experiment

Adult female wistar rats weighting about 170 g to 220 g were obtained from the LPPT Universitas Gadjah Mada Yogyakarta. All the animals were fed with pellet and water was allowed ad libitum under strict hygienic conditions. Before initiation of experiment, the rats were acclimatized for a period of 14 d standard environmental conditions such as temperature (25 °C ± 2 °C), relative humidity (45 % to 55 %) and 12 h dark/light cycle were maintained in the quarantine. The handling of the animals was approved by the Universitas Gadjah Mada Ethical Committee for the care and use of laboratory animals.

Rats were single injected intraperitoneally with a freshly prepared solution of alloxan monohydrate in normal saline at a dose (150 mg kg^{-1} BW) freshly dissolved in 0.9 % NaCl (pH 7). Alloxan monohydrate is capable of producing fatal hypoglycemia as a result of massive pancreatic insulin release thus rats were given with 20 % glucose solution orally after 6 h. The rats were then kept for the next 72 h. After 2 wk, the fatal hyperglycemia rats were chosen for the experiment (i.e., with blood glucose levels of 200 mg · dL^{-1}) [11]. Six groups, five in each received the following treatment. Normal control (G1), Alloxan–diabetic rats without treatment (negative control, G2), alloxan–diabetic rats treated with Glibenclamide (Positive control, G3), alloxan–diabetic rats treated with Na-alginate 200 mg kg^{-1} (G4), alloxan–diabetic rats treated with Na–alginate 400 mg kg^{-1} (G5), and alloxan–diabetic rats treated with Na-alginate 600 mg kg^{-1} (G6). Every subject received the treatment by oral administration for 15 d.

The rats were fasted for 8 h to12 h before blood sample collection. The preprandial and postprandial glycemia were determined using a commercially available glucose kit based on "GOD-PAP" enzymatic photometric test according to the manufacturer's instruction [12]. Dose of glucose for administration was 2 g kg^{-1} [13, 14].

Lipid profile including the total cholesterol, HDL-c, and LDL-c were determined using a commercially available cholesterol kit based on "CHOD-PAP" enzymatic photometric test. Triglyceride levels were measured using enzymatic photometric test with glycerol-3-phospate-oxidase (GPO). The methods were used according to the manufacturer's instruction [12].

2.4 Statistical Analysis

Data were presented as means ± standard deviation (SD). *In vivo* test data were analyzed by ANOVA (Analysis of Variance) with a confidence level of 95

%. Where there were a significant difference then continued with DMRT (Duncan Multiple Range Test).

3.0 RESULTS AND DISCUSSION

3.1 Yield, Water Content, and Viscosity of Na-alginate

The yield of Na-alginate that was extracted from *T. ornate* was 24.69 % ± 7.89 %. The water content and viscosity were 13.32 % and 245.78 cps, respectively (1 cP or cps = 1 mPa s). The yield of Na-alginate in this study had a higher compared to several species of brown algae used in research of Rashid [8] and produced already fulfill the requirements established by the FAO [16]. Rashid [8] reported that levels of water content of some species of brown algae ranges from 15 % to 25 %. Rashid [8] also reported the Na-alginate viscosity of brown algae from different locations showed *T. conoides* (Gili Petagan) 134 cps, *T. decurrens* (Sumbawa) 335 cps, *Sargassum polycystum* (Batunampar) 503.70 cps, *T. ornata* (Gili Rifle) 335 cps, and *S. polycystum* (Sumbawa) 390 cps. The differences viscosity alginate can be caused by a type of seaweed, differences in locations where growing (water conditions, pH, salinity, light, depth, nutrients), the quality of the sample [8], and the extraction method [17].

3.2 Characteristics of Na-alginate

Alginate was depolymerized by strong acid. TLC was used for purity of the homo-oligosaccharides obtained. Each oligosaccharide fraction gave a symmetrical dot on TLC plate. Two spots were detected in TLC analyses for each sample. Based on TLC analyses, Na-alginate of *T. ornata* and Na-alginate standard were found to be capable of forming a monomeric sugar acid from alginate that were guluronate and mannuronate. In hydrolyzate of Na-alginate of *T. ornate* were identified of guluronate (Rf 0.64) and mannuronate (Rf 0.19). The presence of guluronate (Rf 0.64) and mannuronate (Rf 0.2) were also identified on Na-alginate standard. The Rf values identification shows same value between unknown substance and standard may have same or similar characteristic [18].

The FTIR spectrum of Na-alginate of *T. ornata* showed similar bands to those Na-alginate standard in 3 500 cm^{-1} to 1 300 cm^{-1} region while the fingerprints region has two bands at 948.98 cm^{-1} and 871.82 cm^{-1} (Figure 1). Sodium alginate of *T. ornata* showed eight characteristic bands which also could be found at sodium alginate standard (Table 1). According to literature, the band at 3 400 cm^{-1} assigned to the hydrogen bonded O-H stretching vibrations and weak signal at 2 931.80 cm^{-1} due to C-H stretching vibrations [19] and the asymmetric stretching of carboxylate O-C-O vibration at 1 627.92 cm^{-1}[19, 20]. The band at 1 427.32 cm^{-1} assigned to C-O-H deformation vibration with contribution of O-C-O symmetric stretching vibration of carboxylate group [19, 21]. The band 1 087.85 cm^{-1} might be assigned to C-O and C-C stretching vibrations of pyranose ring [19, 20, 21], the band at 1 033.85 cm^{-1} might be also due to C-O stretching vibrations [19]. The anomeric region of fingerprint (950 cm^{-1} to 750 cm^{-1}) showed two characteristic absorption bands. The band at 948.98 cm^{-1} was assigned to the C-O stretching vibration of uronic acid residues, the one at 871.82 cm^{-1} was assigned to the C1-H deformation vibration of β-mannuronic acid residues [19, 21].
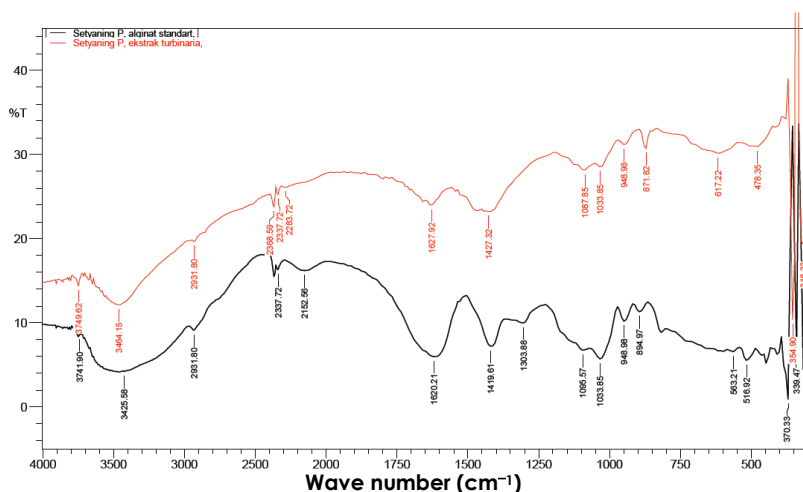

Figure 1 Infrared spectra of Na-alginate standard (red) and Na-alginate of *T .ornata* (black)

Table 1 Signals assigned in the FTIR of sodium alginate of *T. ornata* and sodium alginate standard

Wave number (cm^{-1})		Assignments
Na-alginate standard	Na-alginate of *T. ornata*	
3 425.58	3 464.15	v O-H[a]
2 931.80	2 931.80	v C-H[a]
1 620.21	1 627.92	v asym O-C-O[a,b]
1 419.61	1 427.32	δ C-O-H, vsym COO- (carboxylate ion)[a,c]
1 095.57	1 087.85	v C-O, vC-C (pyranose ring)[a,b,c]
1 033.85	1 033.85	v C-O[a]
948.98	948.98	v C-O (uronic acid residues)[a, c]
894.97	871.82	δ C1-H (β-mannuronic residues)[a, c]

Source:[a][19]; [b][20]; [c][21]

3.3 Effect of Na-alginate of *T. ornata* on Body Weight

Alloxan–induced diabetic rats did not show significantly decrease in body weight after the injection of alloxan. Five groups of diabetic rats had decreased in body weight on 15 d treatment and there were significantly different between the groups of rats. There was not significantly difference between diabetic control (negative control) compared to positive control and the positive control was not significantly difference compared to alloxan–induced diabetic rats treated with Na-alginate 200 mg kg^{-1}. Alloxan–induced diabetic rats treated with Na-alginate(s) (200 mg kg^{-1}; 400 mg kg^{-1}; 600 mg kg^{-1}) did not show significantly difference between each other. Administration of Na-alginate(s) (400 mg kg^{-1}; 600 mg kg^{-1}) showed significantly difference compared to negative control. The body weight of alloxan–induced diabetic rats treated with Na-alginate 600 mg kg^{-1} was not significantly difference compared to control normal (Table 2).

Table 2 Effect of Na-alginate of *T. ornata* on the body weight in alloxan–induced diabetic rats

Group	Body weight (g)				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	188.60 ± 10.64ns	161.40 ± 21.89ns	150.20 ± 24.15a	147.20 ± 19.39a	135.25 ± 21.55a
Positive control	189.20 ± 9.80ns	166.00 ± 14.37ns	159.40 ± 13.70a,b	152.80 ± 16.4a,b	148.60 ± 19.02a,b
Alginate 200 mg · kg^{-1}	201.00 ± 7.91ns	173.20 ± 9.73ns	171.20 ± 12.32a,b	165.80 ± 16.3a,b,c	162.80 ± 14.94b,c
Alginate 400 mg · kg^{-1}	196.20 ± 6.46ns	169.20 ± 3.03ns	170.00 ± 4.00a,b	173.40 ± 5.81b,c	173.20 ± 5.36c
Alginate 600 mg · kg^{-1}	192.60 ± 7.50ns	173.40 ± 1.45ns	174.60 ± 16.16b,c	174.60 ± 12.6c,d	175.40 ± 13.20c,d
Normal control	187.60 ± 2.30ns	187.60 ± 4.16ns	190.00 ± 5.70c	188.60 ± 3.36d	188.40 ± 3.78d

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

The lowering of rats body weight treated by alginate in this study showed lower than study conducted by Wikanta *et al.* [22] using κ-carragenan and *i*-carragenan. In those research, κ-carragenan increased the weight by 34.1 g and *i*-carragenan increased the weight by 30.1 g from the body weight on alloxan–induced diabetic rats after 15 d treatment. The significant reduction in total body weight could be attributed to the loss of fat from adipose tissue and catabolism of amino acids in muscle tissue [23].

3.4 Effect of Na-alginate on Blood Glucose

Alloxan is a urea derivative which causes selective necrosis of the pancreatic islet β-cells [24]. Alloxan and its reduction product dialuric acid establish a redox cycle with the formation of superoxide radicals [25]. Preprandial blood glucose levels determined as fasting blood glucose. Fasting is defined as no calories intake for at least 8 h [1]. Diabetes is diagnosed when the fasting plasma glucose concentration is consistently ≥ 7 mmol L^{-1} (126 mg dL^{-1}) or when the 2-h plasma glucose concentration (after drinking a 75-g glucose load) is consistently ≥ 11.1 mmol · L^{-1} (200 mg · dL^{-1}) [26].

Administration of alloxan led to a significant increase of preprandial blood glucose levels in rats after 3 d. Administration of Na-alginate(s) (200 mg kg^{-1}; 400 mg kg^{-1}; 600 mg kg^{-1}) significantly reduced blood glucose level compared to diabetic control. Dose of 200 mg kg^{-1} and 400 mg kg^{-1} of Na-alginate did not show significantly difference compared to normal control and positive control (Table 3). The result was supported by previous studies using fiber to decrease preprandial blood glucose. Nelson *et al*. [27] used high indigestible fiber and low indigestible fiber diet to decrease preprandial blood glucose in diabetic dogs for 8 mo which resulted high indigestible fiber significantly reduces preprandial blood glucose better than low indigestible fiber. Nelson *et al*. [28] used similar treatment in diabetic cats for 24 wk and showed high fiber indigestible fiber gave better effect on decreasing preprandial blood glucose than low indigestible fiber. Chandalia *et al*. [21] compared the amount of fiber was given to diabetic patients according to American Diet Association (8 g digestible fiber and 16 gindigestible fiber) and rich fiber diet (25 g digestible fiber and 25 gindigestible fiber) for 6 wk. Rich fiber diet decreased 13 % preprandial blood glucose lower than ADA diet.

Normal postprandial blood glucose level is < 180 mg · dL^{-1}[1]. In normal state, postprandial blood glucose level increases less than 50 mg dL^{-1} from prepradial blood glucose level after carbohydrate intake [29]. Alloxan induced diabetic rats postprandial blood glucose level surpassed 200 mg kg^{-1} after 3 d of injection. After 15 d treatment the result was administration of Na-alginate(s) (200 mg·kg^{-1}; 400 mg

kg^{-1}; 600 mg kg^{-1}) significantly reduces postprandial blood glucose levels on rats compared to diabetic control (P < 0.05). However, it failed to restore the level to that of normal control group and positive control group (P < 0.05). Positive control group could restore postprandial blood glucose level in the same level as normal control group (Table 4).

Table 3 Effect of Na-alginate of *T. ornata* on the preprandial blood glucose in alloxan–induced diabetic rats

Group	Preprandial blood glucose (mg · dL^{-1})				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	100.36 ± 6.33^{ns}	167.17 ± 29.12^{a}	158.16 ± 13.63^{a}	195.34 ± 6.56^{a}	208.57 ± 70.60^{a}
Positive control	105.32 ± 2.76^{ns}	149.40 ± 29.12^{a,b}	127.35 ± 11.24^{b}	86.09 ± 23.25^{b}	86.29 ± 13.83^{b}
Alginate 200 mg · kg^{-1}	107.95 ± 4.52^{ns}	150.06 ± 31.02^{a,b}	131.99 ± 33.43^{a,b}	102.74 ± 19.69^{c}	108.50 ± 11.28^{c}
Alginate 400 mg · kg^{-1}	107.88 ± 4.02^{ns}	120.09 ± 15.88^{b,c}	125.92 ± 7.28^{b}	101.61 ± 11.40^{c}	96.55 ± 15.65^{b,c}
Alginate 600 mg · kg^{-1}	101.30 ± 7.98^{ns}	160.94 ± 36.19^{a,b}	127.30 ± 17.73^{b}	100.50 ± 5.60^{c}	99.03 ± 14.26^{b,c}
Normal control	105.26 ± 5.78^{ns}	94.43 ± 11.37^{c}	99.80 ± 3.07^{c}	94.33 ± 3.81^{b,c}	106.06 ± 11.33^{b,c}

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

Table 4 Effect of Na-alginate of *T. ornata* on the postprandial blood glucose in alloxan-induced diabetic rats

Group	Postprandial blood glucose (mg · dL^{-1})				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	130.18 ± 13.51^{ns}	330.44 ± 47.91^{a}	356.64 ± 45.55^{a}	381.61 ± 11.67^{a}	360.48 ± 40.80^{a}
Positive control	136.69 ± 12.80^{ns}	331.25 ± 41.71^{a}	231.38 ± 8.26^{b}	177.45 ± 16.09^{b}	140.75 ± 9.16^{b}
Alginate 200 mg · kg^{-1}	127.37 ± 8.35^{ns}	331.90 ± 33.11^{a}	314.76 ± 31.46^{c}	286.46 ± 29.33^{c}	257.08 ± 34.20^{c}
Alginate 400 mg · kg^{-1}	131.76 ± 9.32^{ns}	341.40 ± 52.58^{a}	285.32 ± 22.40^{c}	250.78 ± 20.93^{d}	238.61 ± 21.48^{c}
Alginate 600 mg · kg^{-1}	130.14 ± 10.10^{ns}	293.61 ± 41.10^{a}	240.83 ± 27.20^{b}	218.18 ± 15.21^{e}	196.05 ± 18.22^{d}
Normal control	132.44 ± 6.34^{ns}	136.62 ± 8.82^{b}	148.48 ± 14.27^{d}	134.08 ± 7.01^{f}	133.05 ± 15.81^{b}

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

Wolf *et al.* [30] used 1.5 g sodium alginate to showed its effect on postprandial glucose peak and glucose uptake reduction after 3 h which resulted in line (32.80 ± 3.40) mg dL^{-1} and (1 429 ± 276) mg dL^{-1}. Sodium alginate had reduction effect better than 1.2 g gum arabic and 0.3 g gum guar with postprandial glucose peak (40.40 ± 3.30) mg dL^{-1} and glucose uptake (1 717 ± 433) mg dL^{-1}. Study on the effect of meal containing alginate compared to test meal without alginate by Torsdottir *et al.* [31] showed that postprandial blood glucose levels by meal containing alginate decrease 31 % lower than meal without alginate.

3.5 Total Cholesterol

Diabetes is associated with major abnormalities in fatty acid metabolism. The resulting disturbance results in an abnormal lipoprotein cascade from the large chylomicron through to the small HDL particle [32]. There was not significantly difference (P > 0.05) between six groups of rats after alloxan injection, 5 d treatment and 10 d treatment. Total cholesterol in the serum of negative control was not significantly difference compared to positive control, Na-alginate 200 mg kg^{-1} and 400 mg kg^{-1} treatment, and normal control. Na-alginate 600 mg kg^{-1} was significantly difference compared to negative control (P < 0.05).

Na-alginate dose of 200 mg kg^{-1} and 600 mg kg^{-1} did not show significantly difference (P > 0.05) (Table 5). The result was supported by several previous studies. Suzuki *et al.* [33] evaluated effect of alginate rich guluronic and mannuronic on cholesterol levels in rats fed with diets containing both alginates and cholesterol which resulted to reductions in liver cholesterol in rats fed with each alginate, and significantly lows cholesterol accumulation in mannuronic acid-rich alginate. Ren *et al.* [34] screened 26 species of seaweeds and six polysaccharides from algae to study their effect on lipid in rats fed with basal diet for 28 d treatment. The six polysaccharides were sulfated glucuronoxylorhamman (0.5 %), fucoidan (1 %), sodium alginate (1 %), funoran (2.5 %), porphyran (2.5 %), and agar (2.5 %). Reduction effect of each polysaccharide was 64 %, 65 %, 68 %, 77 %, 88 % and 95 %, respectively, compared to control group. In the end of study, the polysaccharides could restore cholesterol level to the same level as control group.

3.6 HDL-c

HDL-c management on type 2 diabetes is targeting for > 40 mg dL^{-1} (> 50 mg dL^{-1} on female) [1]. HDL particles seem to have anti-inflammatory and antioxidant properties, inhibiting the oxidation of LDL cholesterol and the expression of cellular adhesion

molecules and monocyte recruitment. The HDL may also reduce the risk of thrombosis by inhibiting platelet activation and aggregation [35]. Administration of Na-alginate to alloxan–induced diabetic rats for 200 mg kg^{-1} did not show significant different compared to negative control and positive control (P > 0.05). Na-alginate doses of 200 mg kg^{-1} and 400 mg kg^{-1} were not significantly difference between each other. All of various doses of Na-alginate were significantly difference compared to normal control (P < 0.05) (Table 6).

Ren *et al.* [34] reported hree algal species showed ability to increase HDL-c levels on blood serum of rats. Fucoidan could increase HDL-c levels up to 47 % compared to the control group. Five other polysaccharides, sulfated glucuronoxylorhamman, sodium alginate, funoran, porphyran, agar found increased HDL-c by 31.97 %, 28.93 %, 9.14 %, 3.55 % and 26.90 %, respectively.

Table 5 Effect of Na-alginate of *T. ornata* on the total cholesterol in alloxan–induced diabetic rats

Group	Total cholesterol (mg · dL^{-1})				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	73.40 ± 12.48^{ns}	60.00 ± 12.49^{ns}	66.40 ± 18.43^{ns}	66.80 ± 11.37^{ns}	67.75 ± 16.02^{b}
Positive control	77.00 ± 11.34^{ns}	71.20 ± 19.06^{ns}	69.40 ± 16.97^{ns}	73.60 ± 19.51^{ns}	72.40 ± 15.24^{b}
Alginate 200 mg · kg^{-1}	65.20 ± 15.14^{ns}	61.40 ± 14.74^{ns}	63.20 ± 15.45^{ns}	57.60 ± 11.37^{ns}	55.80 ± 3.42^{a,b}
Alginate 400 mg · kg^{-1}	85.80 ± 9.78^{ns}	76.20 ± 22.34^{ns}	75.40 ± 21.87^{ns}	70.60 ± 17.93^{ns}	65.60 ± 14.47^{b}
Alginate 600 mg · kg^{-1}	82.40 ± 12.72^{ns}	75.80 ± 10.92^{ns}	64.20 ± 12.36^{ns}	58.20 ± 13.50^{ns}	47.80 ± 5.40^{a}
Normal control	70.20 ± 8.44^{ns}	70.80 ± 9.98^{ns}	68.40 ± 12.97^{ns}	72.00 ± 6.16^{ns}	70.40 ± 7.12^{b}

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

Table 6 Effect of Na-alginate of *T. ornata* on the HDL-c in alloxan–induced diabetic rats

Group	HDL-c (mg · dL^{-1})				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	84.60 ± 5.73^{ns}	54.60 ± 11.30^{a}	54.00 ± 13.76^{a}	56.00 ± 12.67^{a}	59.75 ± 9.39^{a}
Positive control	80.80 ± 12.11^{ns}	52.20 ± 11.71^{a}	54.60 ± 10.28^{a}	57.20 ± 9.58^{a}	58.00 ± 7.78^{a}
Alginate 200 mg · kg^{-1}	85.00 ± 10.41^{ns}	57.80 ± 13.59^{a}	51.20 ± 9.33^{a}	58.00 ± 6.40^{a}	61.80 ± 5.57^{a}
Alginate 400 mg · kg^{-1}	84.20 ± 8.64^{ns}	57.80 ± 12.54^{a}	63.60 ± 10.60^{a}	73.20 ± 11.80^{b}	74.80 ± 10.08^{b}
Alginate 600 mg · kg^{-1}	82.40 ± 7.82^{ns}	50.40 ± 12.46^{a}	60.40 ± 8.26^{a}	73.00 ± 8.80^{b}	78.60 ± 10.60^{b}
Normal control	89.80 ± 9.26^{ns}	90.20 ± 14.55^{b}	93.60 ± 4.45^{b}	103.60 ± 4.22^{c}	108.00 ± 6.59^{c}

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

Table 7 Effect of Na-alginate of *T. ornata* on the LDL-c in alloxan–induced diabetic rats

Group	LDL-c (mg · dL^{-1})				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	57.20 ± 11.52^{ns}	43.00 ± 13.04^{ns}	58.00 ± 16.34^{ns}	59.60 ± 9.37^{ns}	60.75 ± 16.52^{a}
Positive control	62.60 ± 11.95^{ns}	56.00 ± 20.43^{ns}	58.40 ± 16.77^{ns}	64.20 ± 12.01^{ns}	65.00 ± 14.05^{a}
Alginate 200 mg · kg^{-1}	52.60 ± 17.09^{ns}	48.00 ± 12.75^{ns}	55.60 ± 14.42^{ns}	49.00 ± 9.59^{ns}	49.60 ± 3.13^{a,b}
Alginate 400 mg · kg^{-1}	71.40 ± 11.78^{ns}	61.40 ± 21.98^{ns}	64.20 ± 9.50^{ns}	58.60 ± 24.47^{ns}	55.60 ± 13.13^{a,b}
Alginate 600 mg · kg^{-1}	71.20 ± 15.22^{ns}	61.40 ± 11.61^{ns}	55.60 ± 11.37^{ns}	49.60 ± 13.13^{ns}	41.00 ± 5.83^{b}
Normal control	55.60 ± 7.99^{ns}	58.80 ± 11.09^{ns}	59.00 ± 12.63^{ns}	56.80 ± 11.28^{ns}	58.80 ± 7.19^{a}

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

Table 8 Effect of Na-alginate of *T. ornata* on the triglyceride in alloxan–induced diabetic rats

Group	Triglyceide (mg · dL^{-1})				
	Baseline	Day 0	Day 5	Day 10	Day 15
Negative control	81.40 ± 11.78^{ns}	69.60 ± 11.78^{ns}	72.20 ± 17.14^{ns}	75.80 ± 15.77^{ns}	77.75 ± 20.90^{ns}
Positive control	73.80 ± 10.77^{ns}	77.40 ± 15.03^{ns}	76.00 ± 10.84^{ns}	76.40 ± 12.93^{ns}	80.40 ± 13.14^{ns}
Alginate 200 mg · kg^{-1}	79.20 ± 13.77^{ns}	74.60 ± 13.01^{ns}	72.60 ± 15.37^{ns}	66.00 ± 21.76^{ns}	63.40 ± 25.41^{ns}
Alginate 400 mg · kg^{-1}	85.00 ± 3.67^{ns}	75.20 ± 11.43^{ns}	73.20 ± 18.03^{ns}	64.40 ± 24.75^{ns}	60.80 ± 13.80^{ns}
Alginate 600 mg · kg^{-1}	75.40 ± 4.98^{ns}	74.00 ± 6.36^{ns}	70.60 ± 14.57^{ns}	60.20 ± 13.12^{ns}	54.80 ± 10.91^{ns}
Normal control	79.20 ± 8.81^{ns}	79.00 ± 9.54^{ns}	74.00 ± 7.68^{ns}	77.20 ± 10.83^{ns}	75.80 ± 10.33^{ns}

Values are means ± SD. Values followed by the same superscript symbol(s) in each column are not significantly different (P > 0.05).

3.7 LDL-c

Collected data of six groups of rats after alloxan injection, 5 d treatment and 10 d treatment did not

show a significant different between each other on LDL-c level on blood serum of alloxan-induced diabetic rats. LDL-c after 15 d administration of Na-alginate(s) (200 mg kg^{-1}; 400 mg kg^{-1}; 600 mg kg^{-1})

was not significantly difference between each other. Na-alginate mg kg^{-1} showed significant different compared to negative control, positive control, and normal control group (Table 7).

Ren *et al*. [34] studied the effect of polysaccharides extracts from algal on LDL-c in blood serums of rats given basal diet for 28 d. The six polysaccharides used on the study decreased LDL-c levels in blood serum. Sodium alginate (1 %) decreased 34.04 % of LDL-c. Five other polysaccharides, sulfated glucuronoxylorhamman, sodium alginate, funoran, porphyran, agar decreased the LDL-c in line with 36.42 %, 37.66 %, 24.33 %, 36 %, and 14 %, respectively, compared to normal control. LDL are not usually increased in diabetes. In part this may represent a balance of factors that affect LDL production and catabolism. A necessary step in LDL production is hydrolysis of its precursor VLDL by LpL. A reduction can happen in this step because LpL deficiency or excess surface apoproteins (C1, C3, or possibly E) decreases LDL synthesis. Conversely, increases in this lipolytic step that accompany weight loss, fibric acid drug therapy, and treatment of diabetes may increase LDL levels. In diabetes a reduction in LDL production may be counterbalanced by decreases in LDL receptors and/or the affinity of LDL for those receptors [36].

3.8 Triglyceride

Triglyceride management on type 2 diabetes is targeting for < 150 mg dL^{-1}[1]. When the glucose levels excess in the blood, glucose will be converted to triglycerides which triacyglycerol synthesis process is known as lipogenesis. Carbohydrates rich meal can lead to increase the process of lipogenesis in the liver and adipose tissue. However, the occurrence of insulin resistance inhibits lipogenesis process makes glucose and free fatty acids levels in blood plasma increased. In the liver, triglycerides accumulation can cause malfunctioning of the liver (fatty liver), or liver cirrhosis in long term [37]. Alloxan–induced diabetic rats did not show a significant different before the injection, after injection and after treatment compare to normal control (P > 0.05). In fact, there was not significantly difference between the groups of treatment. The triglyceride levels remained in normal levels through the given time of the study (Table 8).

Paxman *et al*. [38] studied the effect of alginate contain drink in obese patient. The subject got 1.5 g alginate contain drink and 0.25 g hydroxypropyl cellulose contain drink as control group for 14 d. Triglyceride levels did not show a significant different between alginate treatment group and control group. Ren *et al*. [34] used six polysaccharides from algal species as treatment for rats given basal diet for 28 d. All of the polysaccharides used in this research had ability to reduce triglyceride levels as good as their ability reducing LDL-c in blood serum. Funoran and sulfated glucuronoxylorhamman reduced

triglyceride levels between 46 % and 64 % compared to control group. Sodium alginate could decrease triglyceride level to 29 % compared to control group. Fucoidan has the ability to reduce the triglyceride levels lowest by 12 % to 20 % [34].

4.0 CONCLUSION

Administration of sodium alginate from *T. ornata* in alloxan–induced diabetic rats decreased the preprandial and postprandial blood glucose, lowered total cholesterol, increased HDL-c, and lowered LDL-c on dependent dose manner. However, sodium alginate of *T. ornata* did not show any effect on triglyceride. This result can be valuable information to discover alternative therapy to achieve and/or maintain glicemic control and lipid profiles management on diabetes patient.

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