



Antiglycation and Fatty Acids Profiling in Response to Phyocyanin Extracted from *Chlorophyta Ulva lactuca* Algae Loaded on Albumin Nano-particles (ULANP) in Diabetic Rats

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Authors' contributions

This work was carried out in collaboration among all authors. Authors ALAM, EKB, KSB, FAA and SSM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors MAZ, WHA and MHAZ managed the analyses of the study. Authors KSB and FAA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study evaluated the effect of Phyocyanin extracted from *Chlorophyta Ulva lactuca* algae loaded on albumin nano-particles (ULANP) on diabetic rats.

Materials and Methods: Fifty albino rats were divided into 5 groups. GPI: control and GPII: rats were injected with alloxan (75 mg /kg) *i.p* for six consecutive days for induction of diabetes. This group was subdivided into 4 subgroups: GP IIa: (Untreated diabetic): GP IIb: rats were given with ULANP (100 mg/kg). GP IIc: Rats were given ULANP (200 mg/kg) *i.p*. GP IId: Rats were given insulin (100 unit/ day). Serum NO, interleukin-6 glucose, AGEs and fatty acids profile was determined.

Results: Analysis of ULANP by FTIR showed the characteristic band (2100 cm⁻¹~ 3700 cm⁻¹) that is indicated mainly from -COO, - CO and conjugated double bond. These bonds showed spectral bands peak 2985 cm⁻¹ and 2860 cm⁻¹, 2986 cm⁻¹. Administration of ULANP in diabetic rats exerted an anti-inflammatory by lowering NO and IL-6 levels and hypoglycemic effects by decreased glucose and reduced AGEs levels. In addition, ULANP lowered percent of saturated fatty acids while elevated unsaturated fatty acids percent.

Conclusion: It was concluded that, ULANP is a promising effective anti-inflammatory and hypoglycemic agent compared with other therapeutic agents with lower site effects.

Keywords: Antiglycation; fatty acids; phyocyanin; *Chlorophyta Ulva lactuca* algae nano-particles; rats.

1. INTRODUCTION

Diabetes mellitus is considered as the most medical problem worldwide. Most researches focus on the reduction of prevalence of the condition by early predication or minimize its complications that increase morbidity and mortality [1]. Metabolomics is a new research trend to discover different metabolites in different cases (normal and diseases) in biological fluids to use as diagnostic or prognostic or follow up therapeutic protocol [2]. This is allowing an accurate and rapid identification about that disease. Metabolomic strategies present several practical advantages, high throughput and fully automated [3]. Metabolomics profiling of diabetes relate to two different stages of the disease in order to see whether metabolomics profiling might be an early diagnostic and prognostic biomarkers for diabetic. The life styles and food type could affect the metabolomic profiling and hence can be monitored.

Nanoparticles synthesized from natural products are of pharmaceutical importance as they will impact human life. *Chlorophyta Ulva lactuca* algae was found to produce a wide variety of bioactive compounds. Antioxidant, antiproliferation and food supplements. These active compounds like phyocanin have been characterized to have pharmacological and ecological importance [4].

Phyocyanin is a water soluble pigment present in different types of algae. It is an accessory

pigment for chlorophyll. All phycobiliproteins are water-soluble, so they possess biological activities as anticancer and antioxidant. The Saudi coast line in Red Sea contains different species of marine algae [5]. However; there are a few studies on the biological effects of the marine algae in this region. This study was designed to explore anti-diabetic of the *Ulva lactuca* algae extract effect of *Chlorophyta Ulva lactuca* algae loaded on albumin nano-particles (ULANP) as promising drug for chemotherapy. In this study we determined serum fatty acids profile that could be used as a biomarker for the chronic disease but substantially for those which are behind or associated with the disease.

2. MATERIALS AND METHODS

Samples of *Chlorophyta Ulva lactuca* algae was collected at depths of about 25–150 cm from Red Sea at Jeddah. Samples were identified by Staff member of marine biology department at King Abdulaziz University, stored in -20°C till analysis.

2.1 Preparation of Algae Extract

The *Chlorophyta Ulva lactuca* samples were air-dry at room temperature, and was grounded to powder with glass homogenizer. Hundred grams of the sample was extracted by 500 ml methanol for 4 hours at 65°C, then, evaporated by rotary vacuum pump. The residue was washed with distilled water and stored at -20°C till use [6].

2.2 Preparation and Characterization of *Ulva lactuca* Algae Extract Loaded on Albumin Nanoparticles (ULANP)

Ulva lactuca algae extract loaded on albumin nanoparticles (ULANP) was prepared by dissolving 10 mg of extract in 4 ml of 10 mM NaCl with continuous stirring, then add ethanol dropwise until the solution become turbid. 100 µl of glutaraldehyde (10%) was added to enhance particle cross linking with stirring the suspension for 24 hrs at 4°C. The obtained nanoparticles was ultrafiltered by centrifugation (25000×g, 10 min), 5 times and the pellet were dispersed in 10 mM NaCl at pH values of 7.5. Each redispersion step was performed in an ultrasonication bath [7]. Nanoparticles will be characterized by Infrared spectra (FT-IR/NICOLET-ESPN670).

2.3 Identification of Methanol Algae Extract by GC/MS

Methanol extract of algae was dissolved in hexane 95% and identified by GC/MS 5975 (Agilent, CA, USA) system including Agilent 7890 A gas chromatography. In hexane solvent: weight approximate 1.0 mg of extracted algae samples and dissolved in 1 mL of hexane in 2 ml amber LC vials and were kept at -10°C until analysis via gas chromatography mass spectrometry (GC-MS)

2.4 Experiment Animals Design

Handling of animals study was done according to KAU regulations, Jeddah. Fifty male albino rats were included in this study divided into 5 group I: control and Group II injected alloxan (75 mg /kg) i.p. for six consecutive days for induction of diabetes. This group was subdivided into: GP IIa: (Untreated diabetic): GP IIb: rats were giving orally with L-ULANP (100 mg/kg). GP IIc: Rats was given with ULANP (200 mg/kg) ip. GP IId: Rats was given insulin (100 unit/ day). At the end of the experiment (6 weeks). Blood was collected directly from all groups. Serum was used for the determination of NO and interleukin-6 level by using ELISA kit and free fatty acids metabolites by Gas chromatography/ mass spectrum.

2.5 Gas Chromatography Mass Spectrometry

Agilent GCMS 5975 (Agilent, CA, USA) system including Agilent 7890 A gas chromatography equipped with Agilent 5975C-VL MSD mass

spectrometer with Agilent 7693 A automatic liquid sampler was used for analysis of plant extracts. The compound was identified via both electron impact ionization mass spectrum and modified retention indexes (programmed temperature n-alkane based retention index).

2.6 Statistical Analysis

Results were statistically analyzed using SPSS version 21, one-Way ANOVA, Post Hoc, LSD to compare between groups in the same time interval.

3. RESULTS

Chemical analysis of methanol extract of *Ulva lactuca* algae by GC-MS reported in Fig. 1. The GC-MS analysis revealed the presence of saturated and unsaturated fatty acids. The major (Phycocyanin). Fig. 2 showed a Analysis of ULANP by FTIR showed the characteristic band (2100cm⁻¹~ 3700 cm⁻¹) that is indicated mainly from -COO, - CO and conjugated double bond. These bonds showed spectral bands peak 2985 cm⁻¹ and 2860 cm⁻¹, 2986cm⁻¹.

Results in Table 1 revealed that, the levels of inflammatory mediators NO and IL-1 were significantly elevated in comparison with control group (p<0.01 and <0.05) respectively. Treatment with ULANP (100 or 200 mg/kg) resulted in a significant reduction of their levels (p<0.001), the effect was dose depended. In addition, in diabetic group, increased formation of AGEs in comparison with to control group. While treatment with ULANP (100 or 200 mg/kg) showed a significant reduction of glucose and AGEs levels compared with untreated group.

Diabetic rats showed a significant increase in blood glucose and AGEs levels compared with the control group (p<0.001). Treatment of diabetic with either ULANP (100 or 200 mg/kg) resulted in a significant decrease in blood glucose and AGEs compared with the untreated diabetic animals (p<0.001) (Table1). The hypoglycemic effect exerted by ULANP (100 or 200 mg/kg) was dose dependent and better than that induced by insulin (p<0.01).

The identification of individual fatty acids were carried out by GC-MS and presented in Table (1). The peaks related to different fatty acids at different retention times (RT) were shown in Fig. (1), some of these peaks were detected and identified, while others about (3.43%) were

unidentified. Results in Table 1 showed that 11 fatty acids were identified and detected in the oil extracted from borage seeds, some of these fatty acids were saturated represented (13.26% of total fatty acids) as Lauric, palmitic, stearic and arachidic acid, and the most predominant saturated fatty acid was palmitic acid (7.64%). Seven unsaturated fatty acids were detected and identified including palmitoleic, oleic, linoleic, γ -linolenic, brassidic, erucic and nervonic acids, total unsaturated fatty acids represented (83.31% of total fatty acids composition). The unsaturated linoleic acid represented the majority of total fatty acids composition (34.23%) followed by γ -linolenic (24.79 %) and oleic acid.

4. DISCUSSION

Metabolomics is an emerging technology increasingly popular in epidemiology to capture broad-based information about large sample sets [8,9]. It was found that, the prepared ULANP exert potent hypoglycemic effect by lowering blood glucose level and AGEs in diabetic rats compared with untreated group. The treatment is dose dependent and approximately similar to insulin. The current study investigated the role of ULANP against protein glycation in diabetic rats. It was found that, these compounds reduced release of inflammation mediators, thereby delaying the progression to diabetic

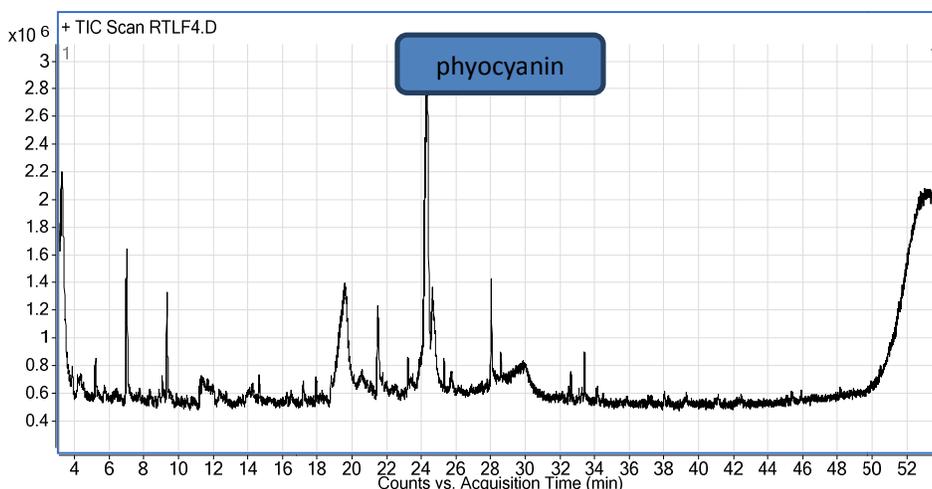


Fig. 1. GC/MS analysis of MEC showed that, measure RI at 1290 and reference RI at 1287. This signal is specific for phyocyanin

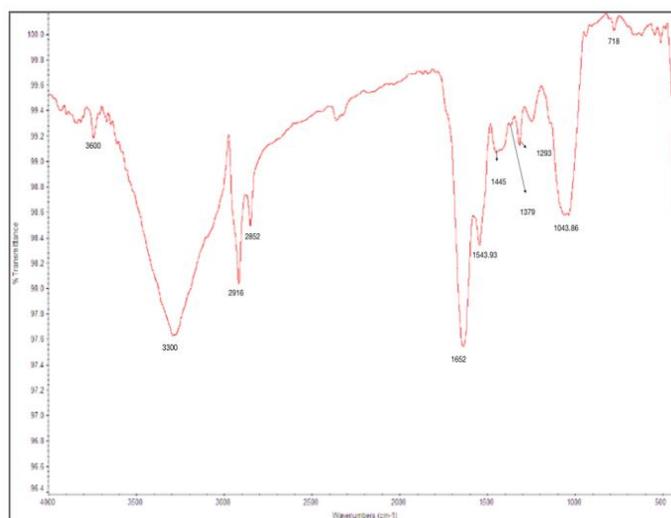


Fig. 2. FTIR spectrum for phyocyanin extract has transmittance maxima at 1652

Table 1. Levels of serum NO, IL-6, glucose and AGEs in all studied groups (Mean±SD)

Groups	NO μ mol/dl	IL-6 μ g /dl	Glucose mg/dl	AGEs μ g/mg protein
Group I Mean + S.D.	40.7 + 3.8	12 + 1.6	80 + 1.7	11 + 1.54
Group IIa Mean + S.D.	262 + 8 ^a	123.6 + 11 ^a	312 + 35 ^a	73 + 6.8 ^a
Group IIb Mean + S.D.	152 + 9 ^{a, b}	99 + 9 ^{a, b}	231 + 22.4 ^{a, b}	42 + 2.6 ^{a, b}
Group IIc Mean + S.D.	63 + 8 ^{a, b}	65 + 3.1	149 + 5.6 ^{a, b}	31 + 2.0 ^{a, b}
Group IId Mean + S.D.	71 + 9	45 + 2.2	101 + 6.6	29 + 1.3

(^a p value, all groups vs control; ^b: p value, treated vs untreated)

Table 2. Serum fatty acids methyl esters as a percentage of total fatty acids in different studied groups

Common name	RT (min)	GPI	GPIIa	GPIIb	GPIIc	GPIId
Palmitic acid	29.66	9.64	13.64	7.64	7.64	7.64
Palmitoleic acid	30.15	8.25	14.25	6.25	6.25	6.25
Stearic acid	30.46	5.08	13.08	3.08	3.08	3.08
Oleic acid	31.08	15.21	10.23	14.23	14.23	14.23
Linoleic acid	32.58	35.10	22.23	34.23	34.23	34.23
γ - Linolenic acid	34.11	22.79	14.79	24.79	24.79	24.79
Arachidic acid	37.10	3.4	2.4	1.4	1.4	1.4
Pentadecanoic acid	29.66	3.64	4.5	8.21	7.11	6.14
Palmitoleic acid	30.15	8.25	14.25	6.25	6.25	6.25
heptadecanoic acid	31.46	7.18	14.01	11.00	9.23	8.1

complications [10-14]. The action of these compounds on protein glycation (AGEs) is related to their suppression of free radicals release, they inhibit the oxidation and the subsequent formation of AGEs. This is due to presence of phycocyanin, it is being to be no toxic for human use. This anti inflammatory agents used as traditional medicine for many diseases.

In current study, diabetic rats showed elevated levels of SFAs and reduced USFAs compared with control group. Rats treated with ULANP (100 or 200 mg) reversed these results. This is in accordance with previous study. The evidence of an association between saturated fatty acids (SFAs) and diabetes are discordant. The relationship between nine SFAs in the plasma with the risk of diabetes was investigated. The study revealed that even-chain SFAs (palmitic acid 16:0 and stearic acid 18:0) were positively correlated with the incidence of diabetes while odd-chain SFAs (pentadecanoic acid 15:0 and heptadecanoic acid 17:0) and longer-chain SFAs (arachidic acid 20:0, behenic acid 22:0, tricosanoic acid 23:0, and lignoceric acid 24:0) were inversely associated with diabetes. Obviously different SFAs have a differential correlation with metabolic risk of diabetes [15-20]. The metabolomic analysis observed that total SFAs, including palmitic acid (C16:0) and stearic acid (C18:0) and monounsaturated fatty acids (MUFAs), were significantly decreased in

individuals exposed to an energy-restricted diet for the 8-week in overweight and obese older adults. Furthermore, palmitoleic acid (C16:1) was found to be a negative predictor of change in body fat loss. Total polyunsaturated fatty acids (PUFAs) significantly decreased, although the overall total amounts of PUFAs did not affected [21-25]. The most specific significant association with diabetes is the variation in the of oleic and linoleic acids.

5. CONCLUSION

It was concluded that, ULAPN is a promising effective anti-inflammatory and hypoglycemic agent compared with other therapeutic agents with lower site effects.

CONSENT

It is not applicable.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Lordan S, Ross RP, Stanton C. Marine bioactives as functional food ingredients: Potential to reduce the incidence of chronic diseases. *Mar Drugs*. 2011;9:1056-100.
2. De Almeida CL, Falcão H de S, Lima GR, Montenegro C de A, Lira NS, de Athayde-Filho PF. Bioactivities from marine algae of the genus *Gracilaria*. *Int J Mol Sci*. 2011; 12:4550-73.
3. Ganesan P, Kumar CS, Bhaskar N. Antioxidant properties of methanol extract and its solvent fractions obtained from selected Indian red seaweeds. *Bioresour Tech*. 2008;99:2717-23.
4. Dhargalkar VK, Neelam P. Seaweed: Promising plant of the millennium. *Science and Culture*. 2005;71:60-6.
5. Ilhami G, Metin TU, Munir O. Evaluation of antioxidant and antimicrobial activities of Clary Sage. *Turk J Agric*. 2003;28:25-33.
6. Ismet B, Cumhuri A, Hilal K. Antimicrobial and antioxidant activities of *Cystoseira crinita* Duby and *Ulva intestinalis* Linnaeus from the coastal region of Sinop, Turkey. *Journal of Coastal Life Medicine*. 2015;3: 441-5.
7. Pietra F. Secondary metabolites from marine microorganisms; bacteria, protozoa, algae and fungi: Achievements and perspective. *Natural Product Reports*. 1997;14:453-64.
8. Kelecom A. Secondary metabolites from marine microorganism. *Annals of Brazilian Academy of Sciences*. 2002;74:151-70.
9. Parekh J, Chanda SV. *In vitro* antimicrobial activity and phytochemical analysis of some Indian medicinal plants. *Turk J Biol*. 2007;31:53-8.
10. Nwinyi OC, Chinedu NS, Ajani OO, Ikpo CO, Ogunniran KO. Antibacterial effects of extracts of *Ocimum gratissimum* and *Piper guineense* on *Escherichia coli* and *Staphylococcus aureus*. *Afr J Food Sci*. 2009;3:77-81.
11. Md. Monir H, Md. Nur A, Nizam U, Mohammad BU, Sk. Ferozuddin AC. *In vitro* antioxidant, antimicrobial and *in vivo* peripheral analgesic activities of methanol and petroleum ether extracts of whole plant of *Uraria lagopoides* DC. *British Journal of Pharmaceutical Research*. 2015;8:1-14.
12. Kuda T, Tsunekawa M, Goto H. Antioxidant properties of four edible algae harvested in the Noto Peninsula, Japan. *Journal of Food Composition and Analysis*. 2005;18:625-33.
13. Finkel T, Holbrook NJ. Oxidants, oxidative stress and the biology of ageing. *Nature*. 2000;408:239-47.
14. Li HB, Cheng KW, Wong CC, Fan KW, Chen F, Jiang Y. Evaluation of antioxidant capacity and total phenolic content of different fractions of selected microalgae. *Food Chem*. 2007;102:771-6.
15. Foon TS, Ai LA, Kuppusamy P, Yusoff MM, Govindan N. Studies on *in vitro* antioxidant activity of marine edible seaweeds from the east coastal region of Peninsular Malaysia using different extraction methods. *J Coast Life Med*. 2013;1:193-8.
16. Duan XJ, Zhang WW, Li XM, Wang BG. Evaluation of antioxidant property of extract and fractions obtained from a red alga, *Polysiphonia urceolata*. *Food Chem*. 2006;95:37-43.
17. Kelman D, Posner EK, McDermid KJ, Tabandera NK, Wright PR, Wright AD. Antioxidant activity of Hawaiian marine algae. *Mar Drugs*. 2012;10:403-16.
18. Rosaline SD, Sakthivelkumar S, Rajendran K, Janarthanan S. Screening of selected marine algae from the coastal Tamil Nadu, South India for antibacterial activity. *Asian Pac. J. Trop. Biomed*. 2012;2:S140-S46.
19. Harborne JB. *Phytochemical methods: A guide to modern techniques of plant analysis*. 3rd edition, New York, Chapman and Hall. 1998;1-150.
20. Ranganathan A. Phytochemical analysis of *Carallum anilagiriana* using GC-MS. *J. Pharmacog and Phytochem*. 2014;3:155-9.
21. Rajesh PM, Natvar PJ. *In vitro* antioxidant activity of coumarin compounds by DPPH, Super oxide and nitric oxide free radical scavenging methods. *Journal of Advanced Pharmacy Education and Research*. 2011; 1:52-68.
22. Premalatha M. Phytochemical characterization and antimicrobial efficiency of seaweed samples, *Ulva fasciata* and *Chaetomorpha antennina*. *International Journal of Pharmaand Bio Sciences*. 2011;2:288-93.

22. Shimizu Y. Microalgal metabolites: A new perspective. *Annu. Rev. Microbiol.* 1996; 50:431–465.
23. Fall t, salihovic S, brandmaier S, Nowak C, Ganna A, Gustafsson S, Broeckling CD, Prenni JE, Kastenmuller G, Peters A. Non-targeted metabolomics combined with genetic analyses identifies bile acid synthesis and phospholipid metabolism as being associated with incident type 2 diabetes. *Diabetologia.* 2016;59:2114-2124.
24. Ferrannini E, Iervasi G, Cobb J, Ndreu R, Nannipieri M. Insulin resistance and normal thyroid hormone levels: Prospective study and metabolomic analysis. *American Journal of Physiology-Endocrinology and Metabolism.* 2017;312: E429-E436.
25. Ferrannini E, Natali A, Camastra S, Nannipieri M, Mari A, Adam KP, Milburn MV, Kastenmuller G, Adamski J, Tuomi T. Early metabolic markers of the development of dysglycemia and type 2 diabetes and their physiological significance. *Diabetes.* 2013;62:1730-1737.

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