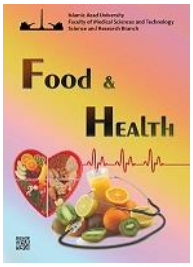

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Effects of spirulina-enriched yogurt on FBS and MDA levels in type 2 diabetic patients

Ayda Ghaffari Ashtiani [1], Anousheh Sharifan [1*], Morteza Gharibi [2], Rahmatollah MoradZadeh [3]

[1] Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran
[2] Department of Emergency Medicine, School of Health, Arak University of Medical Sciences, Arak, Iran
[3] Department of Epidemiology, School of Health, Arak University of Medical Sciences, Arak, Iran

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ABSTRACT

Diabetes is a condition where the body cannot regulate blood sugar levels properly due to insufficient or ineffective insulin. This can cause problems with blood lipids and oxidative stress, which damage cells and tissues. MDA, a product of lipid peroxidation, measures oxidative stress. Functional foods are foods that have health benefits beyond nutrition. They can modulate physiological functions, enhance immunity, prevent diseases, or improve health outcomes. One of the functional foods that can prevent or reduce the complications of diabetes is spirulina-enriched yogurt, which has antioxidant and hypoglycemic properties. In this study, we chose low-fat yogurt as a functional food and enriched it with spirulina algae powder. Spirulina is a blue-green algae with antioxidant, anti-inflammatory, and hypoglycemic properties. It contains various nutrients, such as protein, vitamins, minerals, and phytochemicals, that can scavenge free radicals and protect cells from oxidative stress. We investigated the effect of daily consumption of spirulina-enriched yogurt on fasting blood sugar (FBS) and serum MDA levels in patients with type 2 diabetes.

1. Introduction

Spirulina platensis is a microscopic and filamentous cyanobacterium that is rich in proteins (60-70%) (1), essential fatty acids, vitamins, trace elements (zinc, magnesium, manganese, selenium) and anti-oxidative components (2, 3) and is a rich source of biological products including antioxidants, and granules compounds (phycocyanin, chlorophyll, myxo-xanthophyll, beta-carotene, zeaxanthin, and xanthophyll) (4) with anti-inflammatory, and immune-stimulating effects (5). *Spirulina,* or *Arthrospira* is a blue-green alga that became famous after NASA successfully used it as a dietary supplement for astronauts on space missions (6). It is widely used in human and animal nutrition and the cosmetic industry (7). The role of SP on antioxidant markers in the body has been demonstrated in many studies (8). *Spirulina platensis* was recognized as a nutritious food by the United Nations World Food Conference. Due to the high amount of nutritive ingredients, Spirulina can be introduced as a dietary supplement (9). Studies have shown that Spirulina helps reduce body fat and body mass index (BMI) and promotes appetite (10). In today's societies, diabetes is a condition with high blood sugar index due to insulin resistance or destruction of pancreatic β-cells. It is one of the most common metabolic diseases (11). The International Diabetes Federation predicts that at least 194.5 million people worldwide will be diagnosed with diabetes by 2045, most of whom will have type 2 diabetes (10). It is observed that complications such as oxidative stress, lipid peroxidation, an increase of malondialdehyde (MDA), and a decrease in the activity of antioxidant enzymes occur due to hyperglycemia in diabetic people (12). There is a significant association between oxidative stress and the etiology of diabetic complications (13). Long-term complications of diabetes cause damage to the nervous system, kidneys, cardiovascular system, retina, etc. (11). Free radicals are associated with many biochemical pathways such as glucose autoxidation, polyol pathway, and protein glycation (14). Studies show that the oxidation process of lipids increases with the increase of free radicals in the body. The final product of the peroxidation of unsaturated fatty acids in the cell is malondialdehyde (MDA). The amount of malondialdehyde is usually used as an indicator of oxidative

*Corresponding author: Department of Food Science and Technology, Science and Research Branch, Islamic Azad University, Tehran, Iran.

E-mail address: a_sharifan2000@yahoo.com (Anousheh Sharifan).

stress in diabetic patients and many other diseases, such as cancers (15). Lipid peroxidation can cause injury to proteins, lipids, carbohydrates, and nucleic acids and mediators of tissue injury in cardiovascular pathology and cell membrane or internal cellular components destruction (16).

2. Materials and methods

2.1. Ethics code

This article complies with the ethical guidelines and relevant laws. The code of ethics of this survey is IR.IAU.SRB.REC.1401.094. The clinical trial code of this survey is: IRCT 65709

2.2. Spirulina preparation

Spirulina platensis powder was produced by spray drying technology at Berke Sabz Mad Asia (Delijan, Iran). Microbial tests were performed on the above product, and no microbial contamination was observed in the above product.

2.3. Yogurt preparation

Four grams of spirulina powder was added to 100 grams of normal low-fat yogurt for each meal and diabetics were asked to consume 100 grams of fortified yogurt twice a day for three weeks. The yogurts were prepared weekly and provided to consumers each week. 100 ml cups were given to people so that they could measure the exact amount of yogurts consumed daily.

2.4. Clinical trial

Before the study began, all participants were given a written informed consent form to complete. Anthropometric parameters such as height, weight, age, gender, waist circumference, and type of diet were collected as baseline information. Body mass index (BMI, kg/m^2) was calculated. In addition, subjects were interviewed individually for general characteristics, lifestyle habits, and food consumption. Blood pressure was measured with an automatic blood pressure monitor (Breuer Company, Germany) after 15 minutes of rest. During the intervention period of 21 days, participants were asked to continue their usual diet and not to consume any supplements, functional foods or changes in the type of unusual foods. After completing the above steps and announcing that the participants were fully prepared for the intervention, participants were asked to return to the center the next day in a fasting state to perform the pre-test. 10 ml of blood was drawn from the subjects, and the blood samples were immediately sent to the laboratory to separate the serum by centrifuge. FBS and MDA were measured for each patient. Participants were randomly assigned to either a spirulina or placebo group. When subjects entered the study, they selected a numbered sealed envelope containing their random allocation to the spirulina group (intervention) or placebo group (no intervention). Thus, at random, 50 patients received fermented spirulina powder; 50 patients received placebo powder (containing wheat bran-colored powder). Each patient was instructed to mix 100 grams of plain low-fat yogurt with 4-gram packets of the special powder and consume it twice daily for up to 21 days. On the 22nd day, 10 ml of blood was retaken from each patient for follow-up tests.

2.5. Statistical analysis

Mean, and standard deviation were used to describe quantitative variables. Percentage and frequency were used for qualitative variables. To compare the quantitative variables and conduct the analysis in accordance with the objectives of the project, the Kolmogorov–Smirnov one-sample test was used to check the normality of the data. According to this test, a P-value of less than 0.05 means that the data are not normally distributed, and we used non-parametric tests.

3. Results and discussion

Before conducting the research, we performed a laboratory investigation of *Spirulina platensis*, the results of which are summarized in Table 1. A total of 110 patients with type 2 diabetes participated in the plan, but ten people withdrew from the intervention for personal reasons.

Table 1. Chemical investigation of ingredients in *Spirulina platensis* used in the research.

Ingredient	Unit	Results
Protein	g/100	60
Fat	g/100	10
Carbohydrate	g/100	26.5
Vitamin A	IU/100 g	217666.6
Vitamin B_1	mg/100	14.5
Vitamin B_2	mg/100	4.96
Vitamin B_3	mg/100	15.63
Pantothenic acid	mg/100	12.6
Pyridoxine	mg/100	10.2
Folic acid	mg/100	15
Cyanocobalamin	mg/100	1.24
Vitamin C	IU/100 g	10.3
Vitamin D	IU/100 g	23144
Vitamin E	mg/100	2.50

The remaining 100 patients completed the plan and their results are summarized in Table 2. These findings show that consuming 100 ml of yogurt enriched with 4 grams of *Spirulina platensis* powder twice a day significantly reduced fasting blood sugar (FBS) in type 2 diabetic patients (p=0.001). In contrast, the group consuming yogurt with a placebo did not show any decrease in FBS (p=0.015). The table also shows that besides the reduction in FBS, the level of malondialdehyde (MDA) also decreased significantly in the intervention group (p=0.001), while no reduction of MDA was observed in the control group (p=0.76). Chen et al. (17) reported that due to the high level of free radicals in diabetics, lipid peroxidation increases, which can be a cause of cardiovascular diseases. Rostami et al. (18) obtained similar results regarding the improvement of FBS and MDA levels after 8 weeks of

spirulina consumption (as one 4-gram pill per day). However, Lee et al. (19) did not observe any significant change in the plasma level of FBG after 12 weeks of intervention. Pandey et al. (20) showed that the administration of Spirulina affects blood glucose levels and helps control blood glucose levels in induced diabetic animals. Previously, Gheda et al. (21) announced that phycocyanin in Spirulina acts as an antioxidant and reduces lipid peroxidation. Similarly, in this study, a significant decrease in MDA was observed as an indicator of lipid peroxidation reduction in the intervention group.

Table 2. Comparison of clinical parameters before and after consumption of yogurt containing *Spirulina platensis* powder and yogurt containing placebo.

Variables	Intervention group- *Spirulina platensis* yogurt consumers' group N=50		No intervention group- yogurt with placebo consumers group N=50		
	Mean	Std. deviation	Mean	Std. deviation	P. value**
FBS					
Before	150.44	27.85	156.24	46.09	0.001
After	140.44	22.82	161.56	42.95	0.001
P. value*	0.001		0.15		
MDA					
Before	1.34	0.42	1.42	0.39	0.032
After	1.14	0.34	1.51	0.45	0.010
P. value*	0.001		0.76		

P. value*: Comparison of results before and after treatment within intervention and control groups.
P. value**: Comparison of results before and after treatment between intervention and control group.

4. Conclusion

Diabetes causes high blood sugar, increasing free radicals in the body and leading to oxidative stress. Excessive production of free radicals damages nucleic acids, phospholipid walls of cells, and vital proteins of the body. Based on the review of articles, we can conclude that diabetic patients have a higher need for foods containing high antioxidants. Therefore, our formulated product, low-fat yogurt enriched with spirulina algae powder as a functional food, can effectively reduce blood sugar and lipid peroxidation in diabetic patients.

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References

1. Saranraj P, Sivasakthi S. *Spirulina platensis*–food for future: a review. *Asian Journal of Pharmaceutical Science and Technology*. 2014;4(1):26-33.
2. Parikh P, Mani U, Iyer U. Role of Spirulina in the control of glycemia and lipidemia in type 2 diabetes mellitus. *Journal of Medicinal Food*. 2001;4(4):193-9.
3. Aissaoui O, Amiali M, Bouzid N, Belkacemi K, Bitam A. Effect of *Spirulina platensis* ingestion on the abnormal biochemical and oxidative stress parameters in the pancreas and liver of alloxan-induced diabetic rats. *Pharmaceutical Biology*. 2017;55(1):1304-12.
4. Tajvidi E, Nahavandizadeh N, Pournaderi M, Pourrashid AZ, Bossaghzadeh F, Khoshnood Z. Study the antioxidant effects of blue-green algae Spirulina extract on ROS and MDA production in human lung cancer cells. *Biochemistry and Biophysics Reports*. 2021;28:101139.
5. Finamore A, Palmery M, Bensehaila S, Peluso I. Antioxidant, immunomodulating, and microbial-modulating activities of the sustainable and ecofriendly Spirulina. *Oxidative Medicine and Cellular Longevity*. 2017;2017.
6. Karkos PD, Leong SC, Karkos CD, Sivaji N, Assimakopoulos DA. Spirulina in clinical practice: evidence-based human applications. *Evidence-Based Complementary and Alternative Medicine*. 2011;2011.
7. Asghari A, Fazilati M, Latifi AM, Salavati H, Choopani A. A review on antioxidant properties of Spirulina. *Journal of Applied Biotechnology Reports*. 2016;3(1):345-51.
8. Bitam A, Aissaoui O. *Spirulina platensis*, oxidative stress, and diabetes. In Diabetes 2020 (pp. 325-331). Academic Press.
9. Jung F, Krüger-Genge A, Waldeck P, Küpper JH. Spirulina platensis, a super food*? Journal of Cellular Biotechnology*. 2019;5(1):43-54.
10. He X, Zhu Y, Jiang X, Qiu Y, Yin F, Xiong W, Liu B, Huang Y. Spirulina compounds show hypoglycemic activity and intestinal flora regulation in type 2 diabetes mellitus mice. *Algal Research*. 2022;66:102791.
11. Wan XZ, Li TT, Zhong RT, Chen HB, Xia X, Gao LY, Gao XX, Liu B, Zhang HY, Zhao C. Anti-diabetic activity of PUFAs-rich extracts of *Chlorella pyrenoidosa* and *Spirulina platensis* in rats. *Food and Chemical Toxicology*. 2019;128:233-9.
12. Sadek KM, Lebda MA, Nasr SM, Shoukry M. *Spirulina platensis* prevents hyperglycemia in rats by modulating gluconeogenesis and apoptosis via modification of oxidative stress and MAPK-pathways. *Biomedicine & Pharmacotherapy*. 2017;92:1085-94.
13. Dario G, Anthonio C, Giuseppe P. Oxidative stress and diabetic vascular complications. *Diabetes Care*. 1996;19(3):257-67.
14. Aly HF, Mantawy MM. Comparative effects of zinc, selenium and vitamin E or their combination on carbohydrate metabolizing enzymes and oxidative stress in streptozotocin induced-diabetic rats. European Review for Medical and Pharmacological Sciences. 2012;16(1):66-78.
15. Gaweł S, Wardas M, Niedworok E, Wardas P. Malondialdehyde (MDA) as a lipid peroxidation marker. *Wiadomosci lekarskie* (Warsaw, Poland: 1960). 2004;57(9-10):453-5.
16. Wang J, Zhang X. Free-radical-initiated phospholipid oxidations at the air–water interface: The oxidation of unsaturated and saturated fatty acid chains. *The Journal of Physical Chemistry A*. 2021;125(4):973-9.
17. Chen X, Li X, Xu X, Li L, Liang N, Zhang L, Lv J, Wu YC, Yin H. Ferroptosis and cardiovascular disease: role of free radical-induced lipid peroxidation. *Free Radical Research*. 2021;55(4):405-15.
18. Rostami HA, Marjani A, Mojerloo M, Rahimi B, Marjani M. Effect of Spirulina on lipid Profile, glucose and malondialdehyde levels in type 2 diabetic patients. *Brazilian Journal of Pharmaceutical Sciences*. 2022;58.
19. Lee EH, Park JE, Choi YJ, Huh KB, Kim WY. A randomized study to establish the effects of Spirulina in type 2 diabetes mellitus patients. *Nutrition Research and Practice*. 2008;2(4):295-300.

20. Pandey JP, Tiwari A, Mishra G, Mishra RM. Role of *Spirulina maxima* in the control of blood glucose levels and body weight in streptozotocin induced diabetic male Wistar rats. *Journal of Algal Biomass Utilization*. 2011;2(4):35-7.

21. Gheda SF, Abo-Shady AM, Abdel-Karim OH, Ismail GA. Antioxidant and antihyperglycemic activity of *Arthrospira platensis* (*Spirulina platensis*) methanolic extract: In vitro and in vivo study. *Egyptian Journal of Botany*. 2021;61(1):71-93.