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The Efficacy of a Combination of Spirulina Fortified Chicken Breast Protein in Regulating Blood Sugar, Reducing Oxidative Stress, and Enhancing Pancreatic Function in Female Rats with Alloxan – Induced Diabetes

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Abstract: This study aimed to highlight the importance of following a healthy diet – specifically one rich in protein and fiber – due to its significant health benefits , such as regulating blood sugar levels , reducing insulin resistance and oxidative stress caused by free radicals , and boosting immunity. This study utilized a reparation of Spirulina – fortified chicken breast – which had been thoroughly cooked , pressed, dried , and processed into a form suitable for mixing with the standard diet – to feed the animals for 40 days . The subjects were 48 female Wistar rats ,aged 13-14 months and weighing 128-186g .Diabetes was induced using alloxan (156 mg/kg) ,and the animals were divided into three groups of 16 each : Group A (healthy control) , Group B (diabetic control) , and Group C (diabetic group fed a chicken protein blend supplemented with Spirulina). Upon completion of the experiment ,the results demonstrated the blends ability to regulate blood glucose levels, reduce insulin resistance ,and increase levels of glutathione and glutathione peroxidase .Additionally , it lowered malondialdehyde – a clear marker of oxidative stress and inflammation – while restoring the structural integrity of the pancreas (damaged by alloxan) and reactivating beta-cell function.

Keywords: Chicken breast protein , Spirulina supplements , diabetes , antioxidants, oxidative stress.

Introduction

Diabetes is a common condition today ; it is a chronic metabolic disease characterized by elevated blood sugar levels ,impaired cellular insulin receptors , or the pancreas's failure to secrete insulin in the required amounts [1]. AMPK (AMP-activated protein kinase) acts as an energy regulator ; any dysfunction in it increase the risk of serious diseases such as cancer ,cardiovascular disease ,and diabetes [2]. Diabetes affects all age groups including children , adolescents , and the elderly-without exception . The causes vary from person to person; key factors include a poor diet, excess weight, psychological state , family history (heredity), and gender.Indeed, numerous studies have confirmed that women account for a higher proportion of Type 2 diabetes cases compared to men[3]. Adopting a healthy diet rich in low-glycemic-index foods such as complex carbohydrates (grains), proteins (white

meat), and fiber (leafy greens, herbs, and algae) plays a significant role in mitigating the severity of diabetes by lowering blood sugar levels and reducing insulin resistance [4]. In other words, it targets the metabolic disturbances associated with diabetes. Protein serves as a dietary source rich in essential amino acids that build the body and strengthen its immunity; they also possess a high capacity to control elevated blood glucose levels by inhibiting the enzyme dipeptidyl peptidase-4 (DPP-IV) and peptides that stimulate sugar absorption [5]. Protein plays a crucial role in regulating blood sugar levels in many cases of diabetes; however, the blood sugar response to protein varies depending on the type, source, and timing of consumption, as well as whether it is consumed in isolation or alongside other dietary components [6]. Consuming rapidly absorbed proteins (such as whey) leads to a reduction in blood glucose levels by enhancing the efficiency of pancreatic beta cells and increasing insulin receptor sensitivity, compared to slowly absorbed proteins like casein [7]. Furthermore, plant-based proteins play a significant role in lowering blood glucose and glycated hemoglobin (HbA1c) levels more effectively than animal-based proteins [8]. Furthermore, consuming them with fats raises blood sugar levels more than consuming them in isolation [9]. Therefore, it is essential to combine proteins with a dietary component that does not spike blood sugar—such as fiber—making spirulina an excellent choice. It offers both nutritional and therapeutic benefits; due to its low glycemic index, it improves metabolic markers related to blood sugar and healthy HDL cholesterol levels [10]. Spirulina is a blue-green alga belonging to the cyanobacteria family, renowned for being rich in antioxidants, iron, vitamins such as C and B, and protein comprising 60% of its content. It also contains a bioactive compound known as phycocyanin—a pigment that is highly effective at scavenging free radicals and inhibiting lipid peroxidation, while also boosting the activity of antioxidants like glutathione GSH and glutathione peroxidase GPX [11]. It is considered a safe food when consumed at the recommended daily dosage of 2-3 grams an amount effective for combating major conditions such as diabetes and fatty liver disease. Thanks to its chlorophyll and phycocyanin pigments, it reduces intracellular fat accumulation and elevated blood glucose levels [12]. Its therapeutic role extends beyond this to include increasing energy expenditure, breaking down accumulated plasma lipids, and mitigating insulin resistance and diabetes [13]. The phycocyanin pigment in spirulina prevents methylglyoxal-induced dysfunction in the Islets of Langerhans and beta cells while activating Nrf2—a key factor in cellular protection—and PI3K (phosphatidylinositol 3-kinase), an enzyme regulating vital cellular processes; it also inhibits JNK and P38, the latter playing a crucial role in the cellular inflammatory response and heat stress, thus reducing blood glucose and stimulating beta cells in the islets of Langerhans [14]. It also plays an effective role in reducing oxidative stress and inflammation that causes cognitive impairment in animals with STZ-induced diabetes and increases the efficiency of the nervous system [15].

Materials and Methods

Animals

This study utilized 48 female Wistar rats, aged 13-14 months and weighing 126-138g. The animals were housed in specialized cages, provided with a standard diet, and maintained under a 12-hour light/dark cycle for 40 days. They were divided into three groups:

1. Group A: Healthy control group.
2. Group B: Diabetic control group.
3. Group C: Diabetic group treated with a combination of chicken breast protein supplemented with Spirulina.

Note: The Spirulina supplements were obtained from the certified Malaysian company DXN / Iraq.

Induction of Diabetes

Alloxan was used to induce diabetes in female rats at a dosage of 155 mg/kg of body weight. Prior to the experiment, the animals were fasted for a full day, and their blood glucose levels were measured. They were then injected with alloxan—a chemical agent that destroys beta cells and raises blood glucose levels, thereby causing diabetes. The alloxan was prepared by dissolving it in a cold physiological saline solution 0.9% NaCl at a concentration of 2-5 g/100 ml. Following the injection

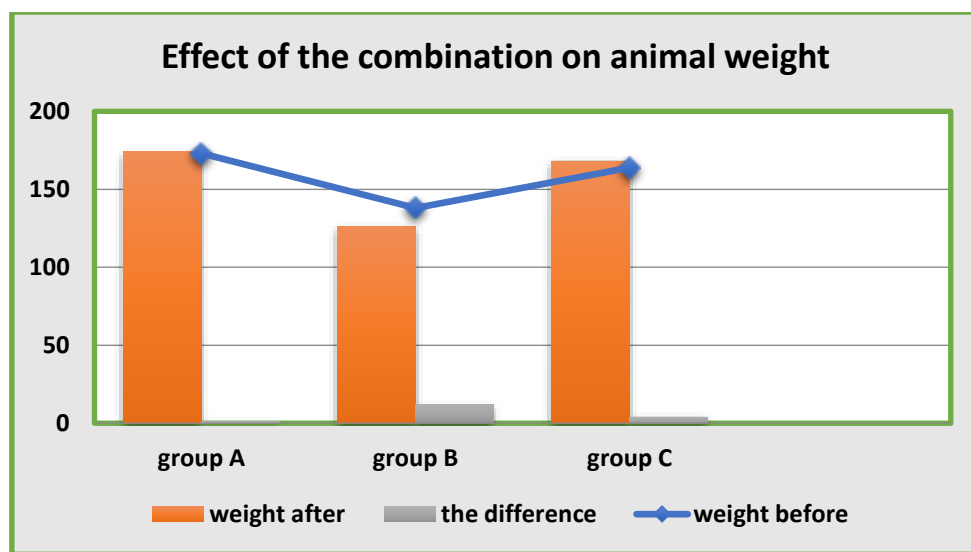
,blood glucose levels were measured again ; a reading of 250 mg/dL indicated that the animal was diabetic . Glucose was administered to prevent the death of the rodents .

Hematological analysis

The animals were fasted for a full day prior to blood collection and dissection for the required analyses . Blood glucose levels were measured ,followed by dissection and the collection of blood via cardiac puncture into specialized tubes for testing .Additionally ,the pancreas was excised and preserved in formalin solution within airtight containers , pending histological staining .

Result and discussion

As shown in Chart1 below , the results indicate a significant decrease in body weight in Group B following the alloxan dose compared to Group A.In contrast ,Group C-fed a combination of chicken breast protein supplemented with Spirulina (a food rich in essential nutrients ,most notably essential amino acids ,vitamins, and antioxidants – showed weight recovery compared to Group B.



(Diagram 1)

This aligns with other studies on inducing diabetes in wistar rats using a dose of 200 mg/kg ,which resulted in a rapid rise in blood glucose and a decrease in body mass [16]. Additionally ,doses 120 mg/kg of alloxan and 40 mg/kg of streptozotocin were used and deemed optimal for inducing diabetes with a low mortality rate, while manifesting key symptoms such as hyperglycemia ,loss of balance ,and a marked reduction in body weight [17]. Diabetes was also induced in 22 Rhesus monkeys using STZ at a dose of 110 mg/kg ,leading to hyperglycemia ,pallor ,vomiting , profuse salivation , and pancreatitis [18].The results shown in Chart 2 below indicate a significant increase ($p < 0.05$) in blood sugar levels in Group B animals following the alloxan dose compared to Group C, which showed a decrease and improvement in blood sugar levels.

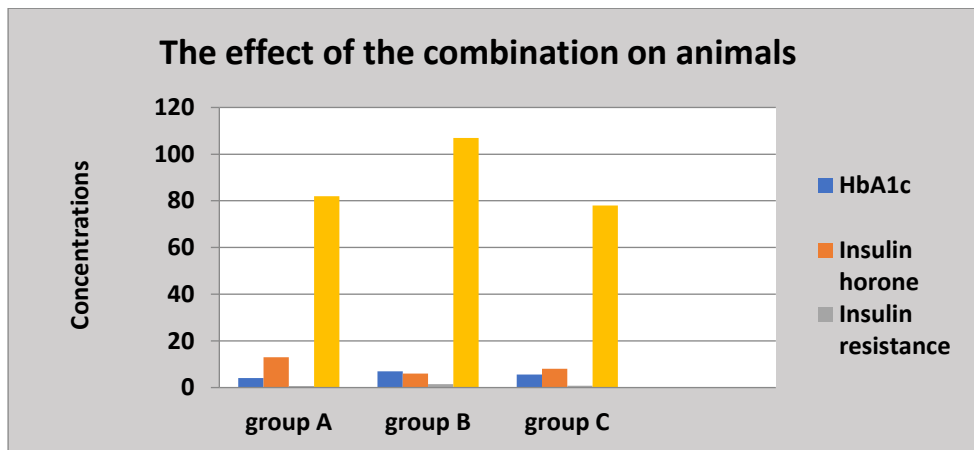


Diagram (2)

These findings align with other studies in which Spirulina supplements 2 g/day for two months were administered to patients with type2 diabetes; this intervention improved metabolic processes and reduced inflammation ,thereby helping to regulate blood sugar and lower HbA1c ,LDL cholesterol , and triglycerides TG ,while increasing levels of beneficial HDL cholesterol [19]. Similarly ,an eight – week regimen of Spirulina supplementation in 30 diabetic patients led to improved insulin secretion and reduced blood glucose and harmful lipid levels [20]. In another study involving Wistar rats with STZ-induced diabetes ,the administration of chicken liver hydro lysates CLH for nine weeks improved glucose levels and reduced insulin resistance, while also increasing protein content in the animals muscles , brains ,and livers [21].The type of protein plays a significant role ; a study examining protein intake – specifically beef ,chicken ,salmon ,and whey proteins in 30 g ,consumed either alone or with rich or peanut butter among individuals with diabetes demonstrated improvements in blood glucose regulation, antioxidant levels , and immune function [22]. Other studies investigating the effects of plant and animal – based high – protein diets on 117 patients with type 2 diabetes over a six – month period showed reductions in body mass and visceral fat, as well as improvements in blood glucose levels, insulin resistance ,liver enzymes , and other biochemical markers [23]. The results shown in Chart 3 below indicate a marked increase in MDA levels, accompanied by a decrease in GSH and GPX levels in the serum of Group B compared to Group C. This demonstrates the efficacy of the antioxidant combination , which raised GSH and GPX LEVELS While reducing MDA – a marker of oxidative stress and free radicals .

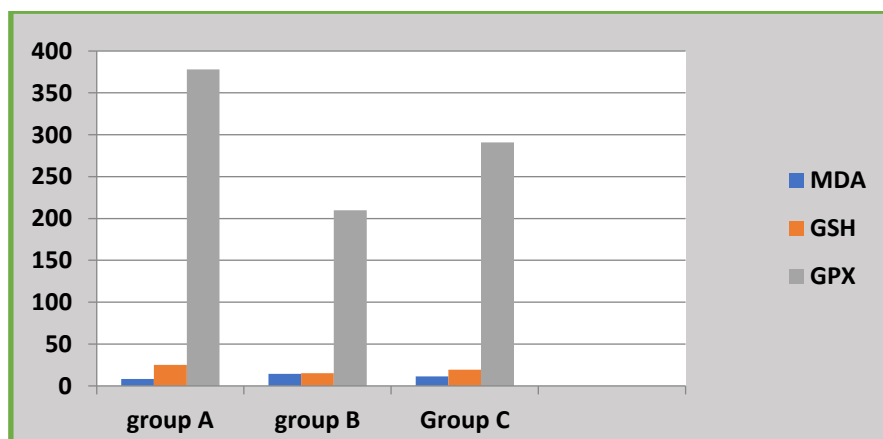
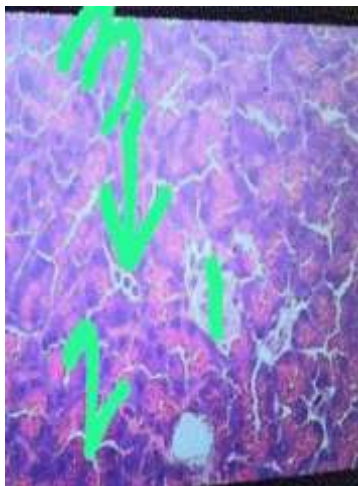


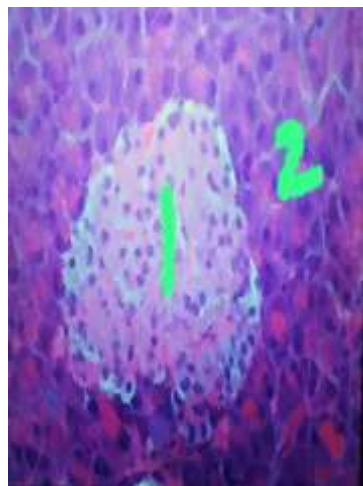
Diagram 3. Effect of the combination on increasing antioxidants and reducing inflammation

These findings align with previous research indicating that feeding diabetic mice 5mg of Spirulina maxima supplements for seven weeks increased levels of the antioxidants GSH and GPX by 71% compared to the control group [24].Studies also noted that daily consumption of 6g of Spirulina

by overweight individuals regulated blood glucose levels and reduced insulin resistance as well as markers of inflammation – such as TNF- α , IL-6 and MDA [25]. Furthermore, it was reported that feeding aged mice a combination of Spirulina 5mg, apple and cucumber for 14 days improved pancreatic beta-cell function and boosted immunity; this effect was attributed to the antioxidant properties of phycocyanin, which elevates GSH and GPX levels while reducing MDA [26]. Furthermore, the consumption of femur bone powder from (cattle, sheep, goats, chickens) at a dosage of 500 mg/kg – following the determination of its chemical composition and amino acid and mineral content – was found to reduce glucose and glycated hemoglobin levels, as well as inflammatory markers such as TNF- α and IL-6 [27]. Finally, the results of the current study – based on the dissection and staining of pancreatic tissues from groups A, B and C – revealed that while the tissues of Group A remained intact, the tissues of Group B exhibited evident hemorrhage, necrosis, and congestion resulting from the alloxan dosage, whereas Group C tissues appeared largely intact, showing only minor congestion, as illustrated in the images below.



A



B



C

These results are consistent with other studies demonstrating the efficacy of *Spirulina platensis* supplementation – at a dosage of 400 mg/kg – in improving the histological structure of the kidneys and pancreas, in contrast to the second model, which exhibited hemorrhage and vacuolization in the pancreatic tissue [28][29]. *Spirulina* and *Chlorella* – whether administered individually or in combination over a 21 day feeding period – exert a potent effect on wound healing, epithelial cell proliferation, and granulation tissue formation in diabetic mice [30]. *Spirulina* also contributed to restoring the structure of spongy bone in diabetic mice, increasing its density while raising vit D levels

, lowering calcium phosphate levels , and boosting immunity [31]. The alloxan dose leads to severe atrophy of the pancreatic Islets of Langerhans , aswell as vacuolization and fatty degeneration of liver cells in rhesus monkeys with induced diabetes [32].

Conclusion

This study concludes that adopting a healthy diet is a fundamental step in preventing numerous diseases, such as diabetes, fatty liver disease, and cardiovascular conditions. Proteins are considered low-glycemic nutrients that help maintain blood glucose levels; they are rich in essential amino acids—building blocks the body cannot produce on its own and must obtain from dietary sources such as white and red meat, eggs, dairy products, and whey. Similarly, fiber (including spirulina) serves as both food and medicine; its high antioxidant content combats free radicals and reduces oxidative stress and inflammatory markers, thereby mitigating the severity of diabetes.

REFERENCES

- [1] S. K. Saban, A. Emre, and D. G. Cigdem, "Evaluation of C-reactive protein/albumin ratio in diabetic retinopathy patients," *Diagnostics*, vol. 15, no. 17, Art. no. 2178, 2025, doi: 10.3390/diagnostics15172178.
- [2] M. Ebrahimi, D. H. Donial, A. Taheri, A. Zand, S. Mohammadi, F. Fattahi, *et al.*, "AMPK signaling in diabetes mellitus, insulin resistance and diabetic complications: A preclinical and clinical investigation," *Biomedicine & Pharmacotherapy*, doi: 10.1016/j.biopha.2021.112563.
- [3] H. Harreiter and A. Kautzky-Willer, "Sex and gender differences in prevention of type 2 diabetes," *Frontiers in Endocrinology*, vol. 9, Art. no. 220, 2018, doi: 10.3389/fendo.2018.00220.
- [4] L. T. Phung, A. Thunyarat, C. Usa, J. R. B. Jamaica, S. Rattan, and A. Thakkestian, "Preventive role of diet interventions and dietary factors in type 2 diabetes mellitus: An umbrella review," *Nutrients*, vol. 12, no. 9, Art. no. 2722, 2020, doi: 10.3390/nu12092722.
- [5] P. Kęska, J. Stangierska, O. Bąkowska, and P. B. Błażewicz, "Meat proteins as dipeptidyl peptidase IV inhibitors and glucose uptake stimulating peptides for the management of type 2 diabetes mellitus: An in silico study," *Nutrients*, vol. 11, no. 10, Art. no. 2537, 2019, doi: 10.3390/nu11102537.
- [6] S. N. Lauren, L. V. Thompson, and M. C. Riddle, "Effects of protein intake on glucagon, insulin, and glucose dynamics: Implications for diabetes," *Frontiers in Clinical Diabetes and Healthcare*, 2026, doi: 10.3389/fcdhc.2025.1712506.
- [7] P. Tessari, E. Kiwanuka, M. Cristiani, M. Zaramella, M. Marcello, C. Zamboni, *et al.*, "Slow versus fast proteins in the stimulation of beta-cell response and the activation of the entero-insular axis in type 2 diabetes," *Diabetes/Metabolism Research and Reviews*, vol. 23, no. 5, pp. 378–385, 2007, doi: 10.1002/dmrr.698.
- [8] E. V. Vigiouliouk, S. E. Stewart, V. H. Jayalath, A. P. Mirrahimi, A. Mozaffarian, R. J. Jenkins, *et al.*, "Effect of replacing animal protein with plant protein on glycemic control in diabetes: A systematic review and meta-analysis of randomized controlled trials," *Nutrients*, vol. 7, no. 12, pp. 9804–9824, 2015, doi: 10.3390/nu7125509.
- [9] A. Nöthlings, F. Böhmer, R. Bock, S. Hummel, F. Lutz, M. Lechner, *et al.*, "Higher glucose concentrations following protein- and fat-rich meals: The Tuebingen Grill study: A pilot study in adolescents with type 1 diabetes," *Pediatric Diabetes*, 2015.
- [10] S. Hu, X. Fan, P. Qi, and X. Zhang, "Identification of anti-diabetes peptides from *Spirulina platensis*," *Journal of Functional Foods*, vol. 56, pp. 333–341, 2019, doi: 10.1016/j.jff.2019.03.024.

- [11] E. H. Hamedifard, S. Gholami, A. Naderi, M. Pahlavani, A. H. Khani, C. T. Chen, *et al.*, "The effect of Spirulina on type 2 diabetes: A systematic review and meta-analysis," *Journal of Diabetes & Metabolic Disorders*, vol. 20, no. 1, pp. 883–892, 2021, doi: 10.1007/s40200-021-00760-z.
- [12] Y. S. Jung, K. J. Kim, J. Choi, E. Kim, and B. Y. Lee, "Spirulina maxima extract reduces obesity through suppression of adipogenesis and activation of browning in 3T3-L1 cells and high-fat diet-induced obese mice," *Nutrients*, vol. 10, no. 6, Art. no. 712, 2018, doi: 10.3390/nu10050712.
- [13] S. Gammone, J. T. T. G. B. Maitane, L. A. Leixuri, I. M. Inaki, M. G. Marcela, I. E. Itziar, A. F. Alfredo, and M. P. Maria, "Anti-obesity effects of microalgae," *International Journal of Molecular Sciences*, vol. 21, no. 1, Art. no. 41, 2019, doi: 10.3390/ijms21010041.
- [14] K. Zarei, F. Asghari, M. Mehrabi, M. A. Mohammed, and Z. Ahmad, "Phycocyanin as a nature-inspired antidiabetic agent: A systematic review," 2023.
- [15] M. Alavi, S. Davoodi, M. Taheri, F. Rahimi, and R. Hosseini, "Spirulina, a dietary supplement, attenuates streptozotocin-induced diabetes by improving cognitive function through anti-inflammatory and antioxidant effects in rats," *Nutritional Neuroscience*, pp. 1–17, 2026, doi: 10.1080/1028415X.2026.2675369.
- [16] I. F. Furman, H. M. McGowan, M. J. Matthews, M. D. Dunn, and W. K. Ward, "Induction of type 1 diabetes mellitus in laboratory rats by use of alloxan: Route of administration, pitfalls and insulin treatment," *Comparative Medicine*, vol. 54, no. 3, pp. 252–257, 2004.
- [17] A. M. Ataralsadat, A. Abdullah, S. K. Seyed, R. Pour, and M. Behdad, "The effects of dosage and the routes of administrations of streptozotocin and alloxan on induction rate of type 1 diabetes mellitus and mortality rate in rats," *Laboratory Animal Research*, vol. 32, no. 3, pp. 160–165, 2016, doi: 10.5625/lar.2016.32.3.160.
- [18] J. M. Kim, J. Shin, B. H. Kim, H. Jang, J. Shin, W. Yoon, G. E. Kim, M. Shin, S. M. Kim, and G. Chung, "Induction, management, and complications of streptozotocin-induced diabetes mellitus in rhesus monkeys," *Xenotransplantation*, vol. 23, no. 6, pp. 472–478, 2016, doi: 10.1111/xen.12266.
- [19] P. P. Parikh, M. Uliyar, and U. Iyer, "Role of Spirulina in the control of glycemia and lipidemia in type 2 diabetes mellitus," *Journal of Medicinal Food*, 2001, doi: 10.1089/10966200152744463.
- [20] H. A. Rostami, M. Abdolijala, M. Mohammad, R. Behdad, and M. Majid, "Effect of Spirulina on lipid profile, glucose and malondialdehyde levels in type 2 diabetic patients," *Brazilian Journal of Pharmaceutical Sciences*, vol. 58, Art. no. e191140, 2022.
- [21] W. Y. Wei, Y. Li, W. Yang, C. H. Huang, Y. H. Yi, and Y. C. Yi, "Functional chicken-liver hydrolysates ameliorate insulin resistance and cognitive decline in streptozotocin-induced diabetic mice," *Poultry Science*, vol. 101, Art. no. 101887, 2022, doi: 10.1016/j.psj.2022.101887.
- [22] X. Li, A. Wang, C. Zhang, S. Brown, K. Adams, M. Miller, S. Anderson, G. Fuchs, S. Thomas, J. Williams, J. Brown, G. Martin, and K. Jones, "Do the types of dietary carbohydrate and protein affect postprandial glycemia in type 1 diabetes?" *Nutrients*, vol. 17, Art. no. 1868, 2025, doi: 10.3390/nu17111868.
- [23] C. R. Camacho, L. M. Navarro, S. P. Ortega, I. G. Ruiz, A. C. Carlos, C. G. López, R. M. García, and I. M. López, "Low-calorie, high-protein diets, regardless of protein source, improve glucose metabolism and cardiometabolic profiles in subjects with prediabetes or type 2 diabetes and overweight or obesity," *Diabetes, Obesity and Metabolism*, 2025, doi: 10.1111/dom.16013.
- [24] M. S. Miranda, R. G. Cintra, S. B. Barros, and J. Mancini-Filho, "Antioxidant activity of the microalga *Spirulina maxima*," *Brazilian Journal of Medical and Biological Research*, 1998, doi: 10.1590/S0100-879X1998000.

- [25] R. S. Rashmi, M. D. Moryam, A. S. Ayoub, S. Seyenden, M. H. Maisa, K. Arne, I. L. Katie, M. W. Katja, B. K. Beat, and Z. Hassane, "Spirulina supplementation with high-intensity interval training decreases adipokines levels and cardiovascular risk factors in men with obesity," *Nutrients*, vol. 15, no. 23, Art. no. 4891, 2023, doi: 10.3390/nu15234891.
- [26] C. Galli, M. H. M. Michael, B. S. Boris, K. C. Kevin, D. B. H. Douglas, and P. C. B. Paula, "Diets enriched in foods with high antioxidant activity reverse age-induced decrease in cerebellar β -adrenergic function and increase in proinflammatory cytokines," *Journal of Neuroscience*, vol. 22, no. 14, pp. 6114–6120, 2002, doi: 10.1523/JNEUROSCI.22-14-06114.2002.
- [27] A. A. Naseh, E. M. Mohamed, H. F. Ahmed, E. A. Youssef, F. H. Abdelrahman, M. A. Ahmed, G. B. Gerhard, U. R. Usama, and A. H. El-Sayed, "Nutritional composition and anti-type 2 diabetes mellitus potential of femur bone extracts from bovine, chicken, sheep, and goat: Phytochemical and in vivo studies," *Nutrients*, vol. 15, Art. no. 4037, 2023, doi: 10.3390/nu15184037.
- [28] I. Hossain, S. Akter, N. Sultana, U. W. Ahmed, A. B. Siddique, T. Akter, and K. Rahman, "Hepato-pancreas protective effects of *Spirulina platensis* in alloxan-induced diabetic rats," *Pakistan Journal of Pharmaceutical Sciences*, 2020.
- [29] K. M. Sadek, M. Lebda, S. M. Nasr, and M. Shoukry, "*Spirulina platensis* prevents hyperglycemia in rats by modulating gluconeogenesis and apoptosis via modification of oxidative stress and MAPK pathways," *Biomedicine & Pharmacotherapy*, 2017, doi: 10.1016/j.biopha.2017.06.023.
- [30] N. M. Naeim, N. A. Naheed, M. V. Mohammadreza, A. Shabani, A. Ebrahimi, T. Mohammadi, R. Fathi, and Z. Shariat, "Effect of *Spirulina* and *Chlorella* alone and combined on the healing process of diabetic wounds: An experimental model of diabetic rats," *Journal of Diabetes & Metabolic Disorders*, 2021, doi: 10.1007/s40200-020-00723-w.
- [31] S. O. Eze, P. N. Choi, H. K. Choi, N. M. Movahed, G. R. A. Gabriele, and P. N. Osei, "Spirulina supplementation improves bone structural strength and stiffness in streptozocin-induced diabetic rats," *Journal of Traditional and Complementary Medicine*, 2021, doi: 10.1016/j.jtcme.2021.07.010.
- [32] T. Deng, S. Li, Q. Jiang, Y. Li, and K. Ma, "Quantitative proteomic analysis of hepatic tissue of T2DM rhesus macaque," *Journal of Diabetes Research*, 2017, doi: 10.1155/2017/3601708.