World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(REVIEW ARTICLE)

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Potential of synbiotic bio-yoghurt with inoculation of probiotic Lactobacillus acidophilus and prebiotic inulin from dahlia tuber (*Dahlia pinnata*) encapsulated with chitosan nanoparticles as diabetes management: A literature review

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World Journal of Advanced Research and Reviews, 2024, 23(01), 2737–2744

Publication history: Received on 16 June 2024; revised on 23 July 2024; accepted on 25 July 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.1.2234

Abstract

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disease characterized by elevated blood glucose levels that can lead to various complications. Lifestyle approaches by consuming healthy foods or beverages are gaining more interest as T2DM management in Indonesia. Synbiotic bio-yogurt with probiotic Lactobacillus acidophilus inoculation and prebiotic inulin from dahlia tuber (Dahlia pinnata) encapsulated in chitosan nanoparticles, is a potential health drink that can be a management of T2DM. This literature review aims to explore the potential of L. acidophilus probiotics, inulin prebiotics, and chitosan nanoparticles as a new approach to T2DM management. The literature search was conducted using scientific databases such as PubMed, Google Scholar, and ScienceDirect with specific keywords related to the research topic. The results of this literature are expected to provide a recommendation in the management of T2DM through synbiotic-based health drink products.

Keywords: Type-2 diabetes mellitus; Synbiotic; *Lactobacillus acidophilus*; Inulin; Dahlia pinnata

1 Introduction

Diabetes mellitus (DM) is defined as a chronic metabolic disease characterised by elevated blood glucose levels, and can lead to macro- and microvascular complications [1]. Type 2 DM (T2DM), characterised by deficiency of insulin secretion by pancreatic cells, tissue insulin resistance, and inadequate compensatory response of insulin secretion, dominates about 90% of the existing DM types. Data from the International Diabetes Federation (IDF) in 2019 states that DM has caused 4.2 million deaths with 463 million adults aged 20 - 79 years living with diabetes in the world. This number is expected to increase to around 700 million by 2045 [2]. The prevalence of DM in Indonesia at the age of >15 years increased from 1.5% (2013) to 2% (2018) and placed Indonesia in 7th place as one of the 10 countries with the most DM patients in 2019 at 10.7 million [3]. This requires special attention considering that T2DM can increase morbidity and mortality in sufferers.

T2DM has become a public health burden because it is associated with huge healthcare costs and high rates of morbidity and early mortality [4]. At the same time, patients with T2DM are more likely to use antidiabetic medications for management than other interventions such as exercise and dietary modification, which are costly [5]. The use of metformin as a first-line treatment for T2DM has been shown to reduce fasting blood glucose by 20% and HbA1c by 1.5% by activating the AMP-activated protein kinase (AMPK) pathway [6]. In addition, dual or combination therapy with other types of antidiabetic agents is often recommended for patients who have difficulty achieving their therapeutic goals. However, despite the considerable benefits, the use of drugs requires frequent dosing and causes greater side effects, leading to therapeutic ineffectiveness and patient non-compliance [5]. Therefore, a lifestyle

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approach to T2DM therapy, particularly the selection of healthy foods or beverages, is needed as an alternative to T2DM management in Indonesia.

A healthy lifestyle approach through nutritious and safe food and beverage products for people with T2DM is potentially the best way to manage diabetes, one of which is through synbiotic products. Synbiotics are actually a combination of good gut bacteria (probiotics) and dietary fibre (prebiotics), which have been shown to have promising effects on glucose homeostasis [7]. Yoghurt is one of the drinks that utilise the goodness of Lactobacillus bulgaricus and Streptococcus thermophilus. However, these two yoghurt starter cultures do not have the ability to survive the intestinal tract and play a minor role in the human gut, including in reducing blood sugar levels in patients with T2DM [8]. In addition, yoghurt generally does not use prebiotics from Indonesia's natural resources.

Currently, bio-yogurt has been developed as a type of yogurt that contains good bacteria strains or probiotics added to yogurt starter bacteria to maximize its therapeutic benefits [9]. The study found that the inoculation of probiotic Lactobacillus acidophilus and prebiotic inulin from dahlia tubers in bio-yogurt was a good combination in normalizing blood glucose levels in patients with T2DM. In addition, encapsulation of synbiotics using nanotechnology has been shown to provide protection from the environment in the digestive tract and increase their viability in the host [10]. Therefore, this literature review aims to determine the potential of synbiotic bio-yogurt from probiotic Lactobacillus acidophilus and prebiotic inulin from dahlia tubers (Dahlia pinnata) encapsulated with chitosan nanoparticles in the management of T2DM. This review is expected to maximize the potential of yogurt products and Dahlia tubers as one of the less explored natural resources of Indonesia for the management of T2DM.

2 Material and methods

2.1 Literature Search

The research method employed in this literature review is a systematic approach to identifying, evaluating, and analyzing relevant literature regarding the potential of synbiotic yogurt inoculated with probiotic Lactobacillus acidophilus and prebiotic inulin from dahlia tubers (Dahlia pinnata) encapsulated with chitosan nanoparticles in diabetes management. This process involves several key stages: (1) literature search using scientific databases such as PubMed, Google Scholar, and ScienceDirect with specific keywords related to the research topic; (2) selection of studies that meet predefined inclusion and exclusion criteria, such as studies published in the last 10 years, studies employing experimental or quasi-experimental designs, and studies assessing the effects of probiotics, prebiotics, or synbiotics on diabetes parameters; (3) data extraction from selected studies, including information on study population, methods, main outcomes, and conclusions; (4) critical analysis and synthesis of results from various studies to identify consistent findings and differences, as well as to assess the quality and biases of these studies; and (5) preparation of the review report presenting the main findings, clinical implications, and recommendations for future research. This method aims to provide a comprehensive and evidence-based understanding of the effectiveness of synbiotic yogurt as an intervention in the management of type 2 diabetes.

3 Discussion

3.1 Synbiotics as Type 2 Diabetes Mellitus Management

Synbiotics are described as a synergistic blend of the advantages provided by both prebiotics and probiotics, with prebiotics enhancing the survival of probiotics in the gut [11]. Probiotics, which include non-pathogenic live microorganisms, benefit the host by improving the balance of gut microbiota and aiding in metabolism [12]. Common examples of probiotic bacteria are Lactobacillus sp. and Bifidobacterium sp [13]. Figure 1 illustrates the mechanism of action and ideal properties of probiotics [11]. In addition, prebiotics are indigestible food components that promote health by selectively stimulating the growth and activity of beneficial gut microbiota (probiotics) [14]. Types of prebiotics that often studied include inulin, fructooligosaccharides (FOS), and galactooligosaccharides (GOS), which are prevalent in many local Indonesian foods. Figure 2 outlines the mechanism of action and ideal properties of prebiotics [11].

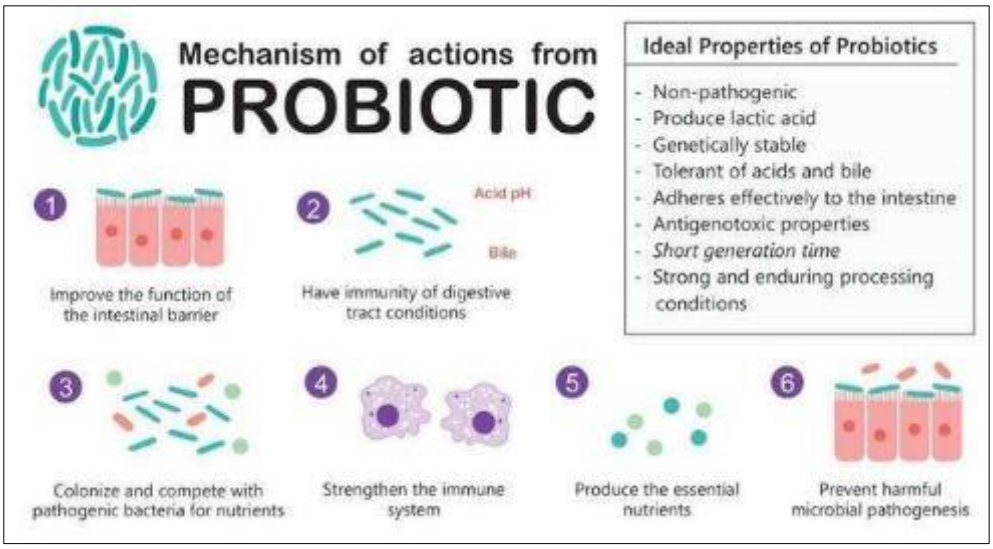

Figure 1 Mechanism and ideal properties of probiotics [11].

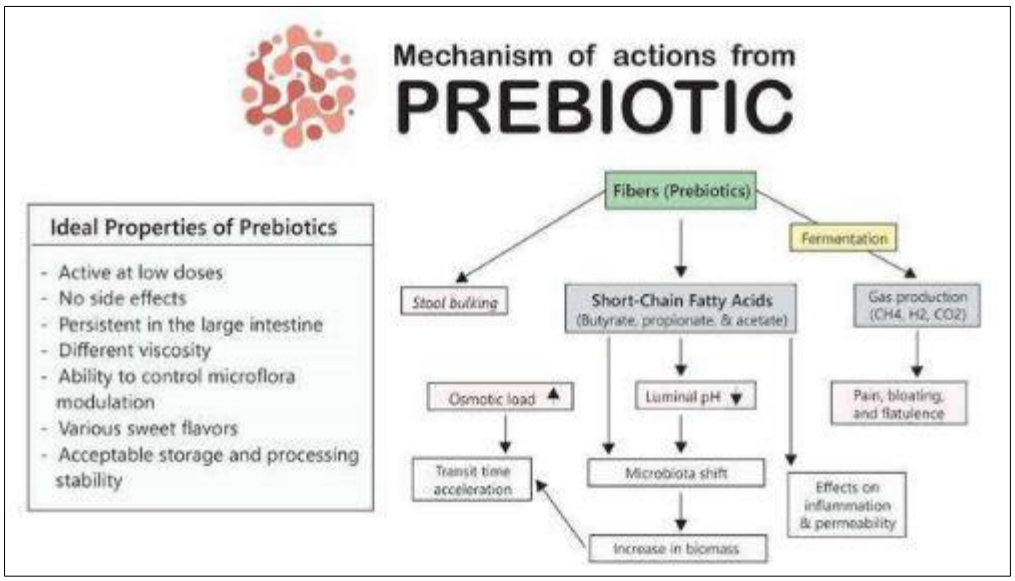

Figure 2 Mechanism and ideal properties of probiotics [11].

Scientific literature suggests that the condition of T2DM may be modulated by the balance of gut microbiota in the body [12]. The interaction of the gut microbiota with its host can lead to the secretion of gut peptides that are important in controlling the physiological processes of energy homeostasis, glucose metabolism, and metabolic inflammation. Disturbances in these interactions indirectly affect glucose metabolism, which is the background of diabetes [12]. Probiotics supported by prebiotics alleviate the pathology of T2DM by improving intestinal defenses, suppressing inflammatory responses, reducing oxidative stress, restoring energy metabolism, and producing beneficial metabolites such as short-chain fatty acids (SCFAs) and bile acids (BAs). In other words, the binding of SCFAs to their receptors leads to the secretion of intestinal peptides such as glucagon-like peptide-1 (GLP-1), which can suppress the insulin resistance that causes T2DM [12]. The mechanism of action of probiotics in the prevention and management of T2DM is shown in Figure 3 [12].

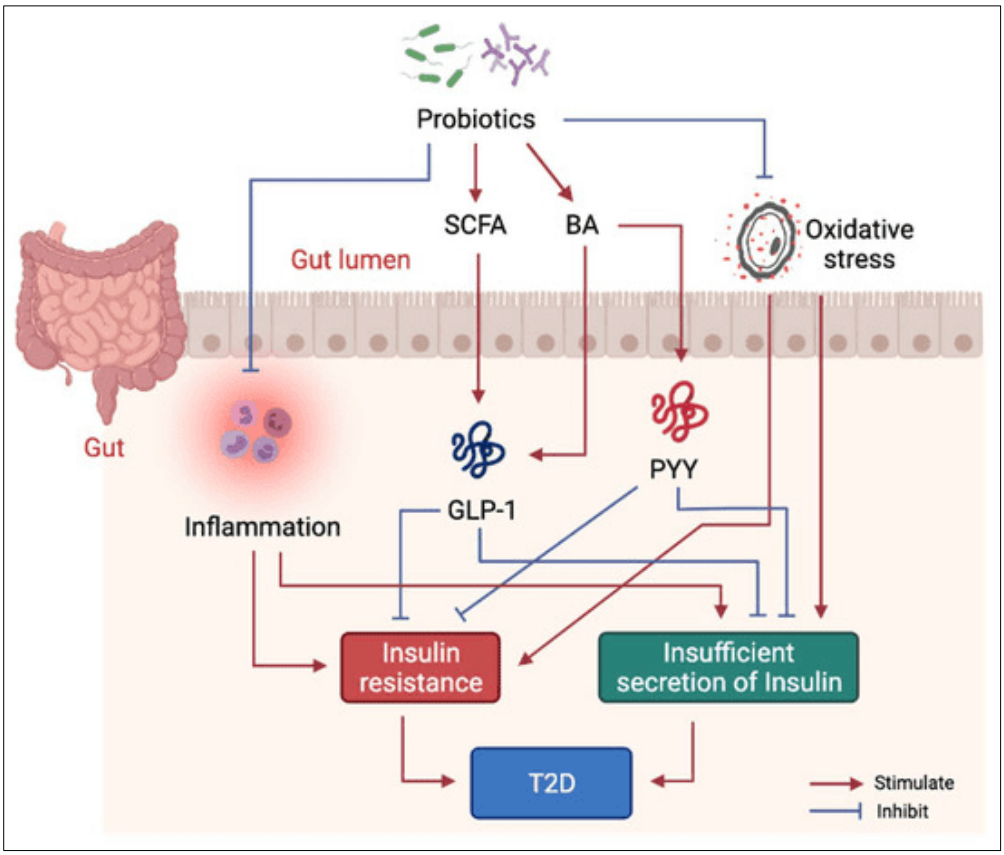

Figure 3 Mechanism of probiotics in prevention and management of type 2 diabetes mellitus [12].

3.2 Potential of Lactobacillus acidophilus as a Source of Probiotics

Lactobacillus acidophilus is a gram-positive bacterium that grows optimally at 37-42°C and can thrive at temperatures as high as 45°C [15]. This bacterium reaches its highest growth at a pH between 5.5 - 6.0 and its growth stops at pH 4.0 [16]. L. acidophilus is an obligate homofermentative organism that ferments carbohydrates to produce lactic acid and is one of the least oxygen tolerant lactic acid bacteria (LAB). L. acidophilus is one of the most important commercial species of lactic acid bacteria available in products such as milk, yogurt, infant formula, and dietary supplements with probiotic effects. Its slow growth in milk suggests that most fermentation in dairy products is achieved by initial culture of yogurt (Lactobacillus delbrueckii subspecies bulgaricus and Streptococcus thermophilus), and L. acidophilus is then added for its probiotic value [17].

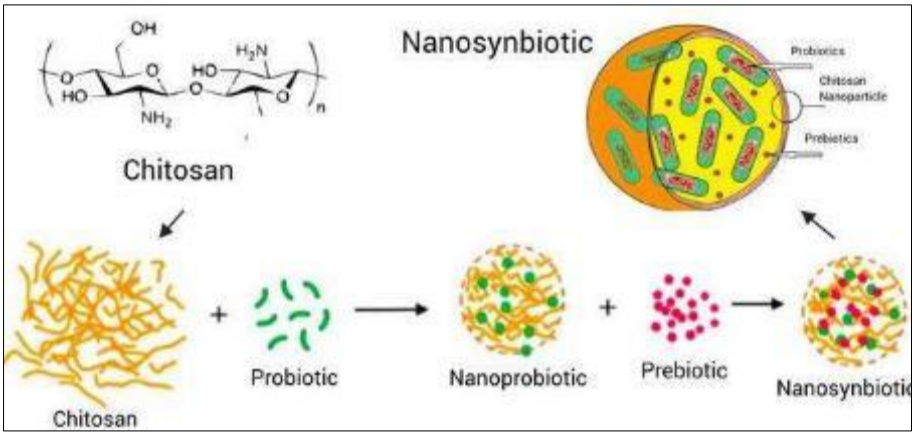

Figure 4 Construction of nanosynbiotics based on chitosan nanoparticles.

According to the research conducted by Yan, L. acidophilus can improve the insulin resistance in T2DM rats. L. acidophilus and L. rhamnosus with DPP-IV inhibitory activity in vitro can increase the level of glucagon-like peptide-1 (GLP-1) in T2DM rats. These results suggest that L. acidophilus may improve T2DM by reducing the oxidative stress status [18]. In addition, a recent study showed that L. acidophilus can improve epithelial barrier function, decrease inflammatory cytokines, and reshape the structure and composition of the gut microbiota, increasing the relative abundance of SCFA-producing bacteria and the levels of SCFAs, especially butyric acid. In addition, butyric acid targets the liver via the portal vein and activates signaling pathways related to glucose and lipid metabolism. Meanwhile, L. acidophilus has high DPP-IV inhibitory activity and probiotic properties in vitro. Administration of this probiotic can maintain blood glucose balance and ameliorate insulin resistance and oxidative stress in T2DM mice [19]. Thus, this strain can serve as a new probiotic in the production of probiotic products, drugs, and functional foods that can reduce fasting blood glucose levels and attenuate biomarkers of type 2 DM [20].

3.3 Potential of Inulin in Dahlia (Dahlia pinnata) Tubers as a Source of Prebiotics

The dahlia flower plant (Dahlia pinnata) is a bulbous shrub typically found in the highland regions of Java and Sumatra. In Indonesia, bulbous plants such as dahlia tubers are rich sources of inulin as a valuable prebiotic. Inulin is favored over other prebiotics because of its high tolerance for consumption, making it safer and free from side effects [21]. It is a polysaccharide made up of fructose molecules, which benefits gut microbiota [21]. Dahlia tubers have an inulin content of approximately 72.6%, which reduces to 41.7% after the extraction process [22]. Inulin is considered safe for consumption, with no toxicity reported in humans or animals at the recommended intake of 10-15 grams per day [23]. The substantial amounts of prebiotics, macronutrients, and micronutrients in dahlia tubers make them a potential food source for managing T2DM in Indonesia.

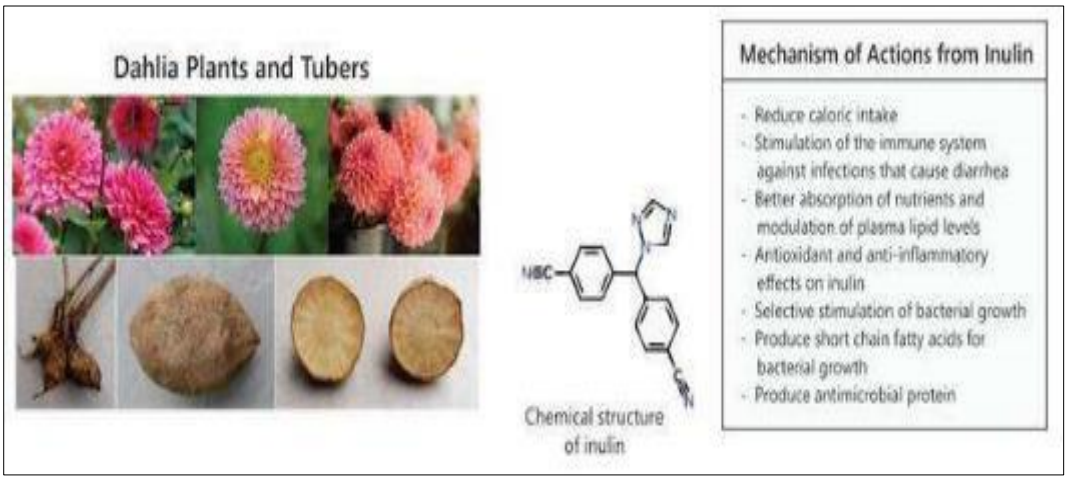

Figure 5 Inulin in Dahlia tubers as source of prebiotics [11]

A randomized controlled clinical trial of women with T2DM who received 10 g/day of inulin supplementation for 8 weeks showed significant reductions in fasting plasma glucose (8.50%) and HbA1c (10.40%) compared to the control group [24]. These findings are supported by a literature review and meta-analysis of randomized controlled trials evaluating the benefits of fructan-type inulin in populations with pre-diabetes and T2DM [25]. The analysis found that 33 studies involving 1346 participants demonstrated that inulin can significantly reduce fasting glucose concentrations, HbA1c, fasting insulin, and homeostasis model assessment-insulin resistance (HOMA-IR). A similar meta-analysis study also found that inulin supplementation for 8 weeks significantly improved the glycemic profile and insulin levels in patients with T2DM [26].

3.4 Potential of Chitosan as a Nanotechnology-Based Synbiotic Nanocarrier

Bio-yogurt products containing probiotics will provide maximum benefits if administered within the minimum recommended levels of 106 - 107 CFU/mL at ingestion. However, the possibility of bacteria not surviving in sufficient numbers in the digestive tract and bio-yogurt products is a major challenge [27]. With the development of nanotechnology in the food products sector, nano-encapsulation of probiotic and prebiotic cells (nanosynbiotics) can protect synbiotics from gastric pH, enzymes and bile salts in the digestive tract and increase their viability and stability in the intestine [28]. The application of this technology aims to produce nano-sized materials and then engineer and redesign these materials into the desired shape, size and function [29]. Nanoparticles used as nanosynbiotics can be derived from natural or synthetic sources and have biodegradable and biocompatible properties because they are in

direct contact with living cells [27]. Therefore, the selection of appropriate nanoparticles is the latest challenge in nanotechnological synbiotic delivery systems.

Chitosan is a polysaccharide obtained from the deacetylation of chitin and has antimicrobial, non-toxic, inexpensive, water soluble, biodegradable and biocompatible properties [29]. Chitosan can be obtained from crustacean skin waste such as shrimp (20-30% chitin), which is very abundant in Indonesia [30]. Chitosan has been used in everyday life, including in the food technology industry, one of which is as a synbiotic nanocarrier. Through extrusion and ionic gelation methods, synbiotics using chitosan as a nanocarrier can be encapsulated into the digestive tract through bio-yogurt products [29]. In vitro studies have shown that encapsulation of L. acidophilus using chitosan nanoparticles can increase the survival, stability and viability of these probiotics in the gastrointestinal environment [27]. Another study mentioned that the addition of prebiotic inulin to probiotic L. casei encapsulated with chitosan nanoparticles increased the viability and survival of probiotics [31]. The study found that chitosan did not alter the sensory quality of the product and thus did not affect the flavor of the food [32]. Despite its antibacterial properties, chitosan has also been shown to have selective properties, increasing the population of probiotic bacteria and significantly decreasing the population of pathogenic bacteria [33]. In conclusion, chitosan is the best nanocarrier to deliver synbiotics to the digestive system through bio-yogurt products.

4 Conclusion

Synbiotic bio-yoghurt with Lactobacillus acidophilus bacteria isolate and inulin prebiotic fortification from dahlia tubers encapsulated in chitosan nanoparticles has the potential to be a solution to normalize blood sugar levels of patients with type 2 diabetes through healthy beverage products. However, further research is needed regarding product development as well as dosage recommendations related to probiotics and prebiotics to ensure safety and effectiveness.

Compliance with ethical standards

Disclosure of Conflict of interest

No conflict of interest to be disclosed.

References

[1] Arnold SV, Khunti K, Tang F, Chen H, Nicolucci A, Gomes MB, et al. Impact of micro- and macrovascular complications of type 2 diabetes on quality of life: Insights from the Discover Prospective Cohort Study. Endocrinology, Diabetes & Metabolism. 2022;5(2).

[2] Galicia-Garcia U, Benito-Vicente A, Jebari S, Larrea-Sebal A, Siddiqi H, Uribe KB, et al. Pathophysiology of type 2 diabetes mellitus. International Journal of Molecular Sciences. 2020;21(17):6275.

[3] Kementerian Kesehatan RI. Tetap Produktif, Cegah dan Atasi Diabetes Melitus [Internet]. [cited 2022Aug19]. Available from: https://pusdatin.kemkes.go.id/resources/download/pusdatin/infodatin/Infodatin-2020-Diabetes-Melitus.pdf

[4] Tinajero MG, Malik VS. An update on the epidemiology of type 2 diabetes. Endocrinology and Metabolism Clinics of North America. 2021;50(3):337–55.

[5] Padhi S, Nayak AK, Behera A. Type II diabetes mellitus: A review on recent drug based therapeutics. Biomedicine & Pharmacotherapy. 2020;131:110708.

[6] Marín-Peñalver JJ, Martín-Timón I, Sevillano-Collantes C, Cañizo-Gómez FJ. Update on the treatment of type 2 diabetes mellitus. World Journal of Diabetes. 2016;7(17):354.

[7] Mahboobi S, Rahimi F, Jafarnejad S. Effects of prebiotic and synbiotic supplementation on glycaemia and lipid profile in type 2 diabetes: A meta-analysis of randomized controlled trials. Advanced Pharmaceutical Bulletin. 2018;8(4):565–74.

[8] Hartayaniei L, Ananingsih K. Bifidobacteria as potential probiotic in yogurt [Internet]. Unika Repository. 1970 [cited 2022Sep1]. Available from: http://repository.unika.ac.id/id/eprint/2088.

[9] Pratiwi IDPK, Nocianitri KA, Aryanta WR, Ramona Y, Sukrama IDM, Sujaya IN. Efek konsumsi bio-yoghurt dari Lactobacillus rhamnosus SKG34 terhadap lipid profile pada manusia. Archive of Community Health. 2013;2(1):40-9.

[10] Ashaolu TJ. Emerging applications of nanotechnologies to probiotics and prebiotics. International Journal of Food Science & Technology. 2021;56(8):3719–25.

[11] Callista VMP, Rahmanto I, Qamar, Khatimah H, Setiabudi RJ. Synbiotic potential of probiotics Lactobacillus plantarum and inulin from Dahlia tubers (Dahlia pinnata) and fortification of nano-Fe as stunting management: future perspective indonesia. IJRP. 2023;131(1): 96-102.

[12] Pandey KR, Naik SR, Vakil BV. Probiotics, prebiotics and synbiotics- a review. J Food Sci Technol. 2015 Dec;52(12):7577-87.

[13] Stavropoulou E, Bezirtzoglou E. Probiotics in Medicine: A Long Debate. Front Immunol. 2020 Sep 25;11:2192.

[14] Lamuel-Raventos RM, Onge MS. Prebiotic nut compounds and human microbiota. Crit Rev Food Sci Nutr. 2017 Sep 22;57(14):3154-3163.

[15] Altermann E, Russell WM, Azcarate-Peril MA, Barrangou R, Buck BL, McAuliffe O, et al. Complete genome sequence of the probiotic lactic acid bacterium lactobacillus acidophilus NCFM. Proceedings of the National Academy of Sciences. 2005;102(11):3906–12.

[16] Shah NP. Functional cultures and health benefits. International Dairy Journal. 2007;17(11):1262–77.

[17] María Remes-Troche J, Coss-Adame E, Ángel Valdovinos-Díaz M, Gómez-Escudero O, Eugenia Icaza-Chávez M, Antonio Chávez-Barrera J, et al. lactobacillus acidophilus lb: A useful pharmabiotic for the treatment of digestive disorders. Therapeutic Advances in Gastroenterology. 2020;13:175628482097120.

[18] Yan F, Li N, Yue Y, Wang C, Zhao L, Evivie SE, et al. Screening for potential novel probiotics with dipeptidyl peptidase IV-inhibiting activity for type 2 diabetes attenuation in vitro and in vivo. Frontiers in Microbiology. 2020;10.

[19] Andreasen AS, Larsen N, Pedersen-Skovsgaard T, Berg RM, Møller K, Svendsen KD, et al. Effects of lactobacillus acidophilus NCFM on insulin sensitivity and the systemic inflammatory response in human subjects. British Journal of Nutrition. 2010;104(12):1831–8.

[20] Ejtahed HS, Mohtadi-Nia J, Homayouni-Rad A, Niafar M, Asghari-Jafarabadi M, Mofid V. Probiotic yogurt improves antioxidant status in type 2 diabetic patients. Nutrition. 2012;28(5):539–43.

[21] Kosasih W, Pudjiraharti S, Ratnaningrum D, Priatni S. Preparation of inulin from Dahlia tubers. Procedia Chemistry. 2015;16:190–4.

[22] Yuliana R, Kusdiyantini E, Izzati M. Potensi Tepung Umbi Dahlia Dan Ekstrak Inulin Dahlia Sebagai Sumber Karbon Dalam Produksi Fruktooligosakarida (fos) Oleh Khamir Kluyveromyces Marxianus DUCC-Y-003. Bioma : Berkala Ilmiah Biologi. 2014;16(1):39.

[23] Ioana, M, Szekely-Varga, Z., & Cantor, M. Dahlia An Unforgettable Flower-A New Perspective for Therapeutic Medicine. Journal of Hop and Medicinal Plants.2017;;1-2.

[24] Dehghan P, Pourghassem Gargari B, Asgharijafarabadi M. Effects of high performance inulin supplementation on glycemic status and lipid profile in women with type 2 diabetes: a randomized, placebo-controlled clinical trial. Health Promot Perspect. 2013 Jun 30;3(1):55-63.

[25] Wang L, Yang H, Huang H, Zhang C, Zuo HX, Xu P, Niu YM, Wu SS. Inulin-type fructans supplementation improves glycemic control for the prediabetes and type 2 diabetes populations: results from a GRADE-assessed systematic review and dose-response meta-analysis of 33 randomized controlled trials. J Transl Med. 2019 Dec 5;17(1):410.

[26] Zhang W, Tang Y, Huang J, Yang Y, Yang Q, Hu H. Efficacy of inulin supplementation in improving insulin control, HbA1c and HOMA-IR in patients with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. J Clin Biochem Nutr. 2020 May;66(3):176-183.

[27] Ebrahimnezhad, P., Khavarpour, M., Khalili, S. Survival of Lactobacillus Acidophilus as Probiotic Bacteria using Chitosan Nanoparticles. International Journal of Engineering, 2017; 30(4): 456-463

[28] Ashaolu TJ. Emerging applications of nanotechnologies to probiotics and prebiotics. International Journal of Food Science & Technology. 2021;56(8):3719–25

[29] Sumeisey G, Umboh SD, Tallei TE. Penyalutan bakteri asam Laktat Menggunakan Nanopartikel Kitosan. Pharmacon. 2019;8(4):843.

[30] Pratiwi IDPK, Nocianitri KA, Aryanta WR, Ramona Y, Sukrama IDM, Sujaya IN. Efek konsumsi bio-yoghurt dari Lactobacillus rhamnosus SKG34 terhadap lipid profile pada manusia. Archive of Community Health. 2013;2(1):40-9.

[31] Darjani P, Hosseini NM, Kadkhodaee R, Milani E. Influence of prebiotic and coating materials on morphology and survival of a probiotic strain of Lactobacillus casei exposed to simulated gastrointestinal conditions. LWT. 2016;73:162–7.

[32] Călinoiu L-F, Ştefănescu B, Pop I, Muntean L, Vodnar D. Chitosan Coating Applications in Probiotic Microencapsulation. Coatings 2019;9:194

[33] Kipkoech C, Kinyuru JN, Imathiu S, Meyer-Rochow VB, Roos N. In Vitro Study of Cricket Chitosan's Potential as a Prebiotic and a Promoter of Probiotic Microorganisms to Control Pathogenic Bacteria in the Human Gut. Foods. 2021 Sep 29;10(10):2310.