Check for updates

Hindawi
Journal of Food Quality
Volume 2023, Article ID 5540118, 11 pages
https://doi.org/10.1155/2023/5540118

WILEY | Hindawi

Review Article

Health Benefits of Okara for the Management of Diabetes Mellitus

Kaisun Nesa Lesa,[1,2,3] **Nazir Ahmad**,[4] **Yunika Mayangsari**,[1]
Mayeen Uddin Khandaker,[5] **Faruque Mohammad Rashed Iqbal**,[2]
Dwi Larasatie Nur Fibri,[1] **and Md Mehedi Hassan**[6]

[1]*Department of Food and Agricultural Product Technology, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia*
[2]*Faculty of Institute of Climate Change, Universiti Kebangsaan Malaysia (The National University of Malaysia), Bangi, Malaysia*
[3]*Department of Nutrition and Food Technology, Jessore University of Science and Technology, Jessore, Bangladesh*
[4]*Department of Pharmacology and Clinical Pharmacy, Faculty of Pharmacy, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia*
[5]*Centre for Applied Physics and Radiation Technologies, School of Engineering and Technology, Sunway University, Bandar Sunway, Selangor 47500, Subang Jaya, Malaysia*
[6]*School of Food and Biological Engineering, Jiangsu University, Zhenjiang 212013, China*

Correspondence should be addressed to Kaisun Nesa Lesa; kaisun_nesa@yahoo.com, Yunika Mayangsari; yunika.mayangsari@ugm.ac.id, and Faruque Mohammad Rashed Iqbal; rashed@ukm.edu.my

Received 14 April 2023; Revised 18 July 2023; Accepted 2 August 2023; Published 14 August 2023

Academic Editor: Timothy Omara

Copyright © 2023 Kaisun Nesa Lesa et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia caused by β-cells destruction and/or insulin resistance. Okara, a byproduct of soybean, contains high amount of dietary fiber (50%), protein (25%), fat (10%), vitamins, and phytochemical components including isoflavones and soyasaponins and has drawn particular attention to its positive benefits on health as a source of fiber-rich food that can help people with diabetes. This review aimed to assemble data as a detailed summary of the health benefits of okara for the management of diabetes mellitus. This review was carried out by identifying relevant literature published from 2010 to 2023 by searching electronic databases. Okara can control diabetes by reducing body weight and delaying digestion and absorption of carbohydrates, thereby increasing satiety and decreasing blood glucose levels. To sum up, okara consumption as a functional food ingredient is beneficial in the management of diabetes.

1. Introduction

Every year, enormous amounts of derivatives are produced during the production of food products made from soybeans (*Glycine max*). Soybean contains high-quality proteins, dietary fiber (DF), and phytochemicals that have a beneficial effect on human health. Okara is a byproduct of soybean [1], enriched in DF (42.4–58.1%), protein (25%) [2], and phytochemical components, including isoflavone, lignin, and phytosterol [3–7]. When soybeans are processed to make soybean curd, about 1.1 kg to 1.2 kg of okara (on a wet basis) are produced from 1 kg of processed soybean. Okara is produced annually in around 1.4 billion tons globally, where the main portion is produced by Asian countries including Singapore (about 10,000 tons), Japan (around 800,000 tons), Korea (about 310,000 tons), China (around 2,800,000 tons) [8, 9], and Indonesia (about 1,024 million tons) [6]. Worldwide, huge amounts of okara are produced with the increase in soybean consumption [10]. Thus, every year large quantities of okara create disposal problems that easily deteriorated the quality of our environment [11, 12]. Therefore, most industries resold the okara as feed for cattle since the protein contents of the okara are still at quite a high level [13] and which is a low impact on the environment. Later, okara has been used as food for humans traditionally [11] and also as a functional ingredient in food products, such as bread, steamed bread, noodles, beverages, and cookies with health-promoting attributes [3, 5, 14, 15]. Its application is widely spread in the food industry in Asian countries, especially in Japan, China, and Indonesia [16], for its high nutritional value and health-promoting effects.

To date, research dealing with okara mainly on DM as a possible health-promoting benefit is being focused. In recent decades, a variety of physiological functional properties of DF are entrenched as isoflavones (genistein and daidzein), essential amino acids (leucine, phenylalanine, isoleucine, methionine, histidine, threonine, valine, and lysine), nonessential amino acids (tyrosine, proline, alanine, arginine, glycine, glutamic acid, serine, and aspartic acid) [17], and peptides in okara that have been reported opposed to metabolic ailments [11, 18], such as diabetes, hyperlipidemia [19], obesity, cardiovascular disease [20], and gut dysbiosis [21]. Diabetes mellitus is one of the largest public health concerning issues; therefore, scientists to pay heed to the potentiality of food-based interventions to combat DM. They also clarified that the consumption of okara as a supplement could lower postprandial blood glucose level (BGL) and has antidiabetic properties [5, 11, 22, 23]. There are numerous clinical evidence and potential health advantages of okara based on functional food ingredients [24].

Previously no such data are summarized based on okara and its health benefits against diabetes. Therefore, this review focused on a detailed discussion on the health benefits of okara for the management of DM.

2. Diabetes Mellitus

DM is referred to as hyperglycemia [25], which arises from the abnormalities of insulin (a hormone that regulates blood glucose) secretion [26]. WHO referred to "DM as a collection of anatomical and chemical problems from the addition of factors in which there is absolute or relative insulin deficiency and impaired insulin function." High BGL (fasting plasma glucose level 7 mmol/L) causes extensive harm to the blood vessels and increased the risk of cardiovascular diseases, renal impairment, leg amputation, loss of vision, and nervous disorder [25–28].

There are two major types of diabetes: insulin-dependent (childhood-onset diabetes) or type 1 diabetes mellitus (T1DM) and noninsulin-dependent (adult-onset diabetes) or type 2 diabetes mellitus (T2DM) [26, 27]. Among other types of diabetes, gestational diabetes (GD), maturity-onset diabetes of the young (MODY), and malnutrition-related diabetes mellitus (MRDM) are also termed as physiological diabetes with less prevalence than T2DM and T1DM [29]. Patients with T1DM require regular insulin administration to control the amount of glucose in their blood [26].

The American Diabetes Association stated that normal blood sugar levels are less than 140 mg/dL (7.8 mmol/L). Prediabetes is indicated as a reading between 140 and 199 mg/dL (7.8–11.0 mmol/L), and diabetes is defined as a reading of greater than 200 mg/dL (11.1 mmol/L) after two hours [30].

Figure 1 describes the main causes of autoimmunity that contribute to the progression of T1DM, activated to initiate crucial cellular immunity against the pancreas, which results in insulitis, inflammatory pancreatic damage, and malfunction of the β-cells that secrete insulin. These may be both internal (hereditary predisposition) or/and external (viral and microbiome) factors. Clinical symptoms, such as hypoinsulinemia, dyslipidemia, and hyperglycemia, may be seen as the prediabetic level that develops into the T1DM (terms as symptomatic) stage [26, 27].

On the other hand, Figure 1 also displays that T2DM normally starts with the passing from normal insulin sensitivity to insulin resistance, which in turn encourages the production and excretion of more insulin (the term known as hyperinsulinemia) to manage normoglycemia (compensated stage). β-cells, however, finally fail to produce enough insulin to balance the increased demand in the context of worsened insulin sensitivity, and the patient progresses to the dysfunctional stage, known as decompensated, in which hypoinsulinemia, hyperglycemia, and dyslipidemia manifest also [26, 27].

DM is one of the top ten causes of death globally [31]. In recent decades, the prevalence of diabetics is significantly increased [32], specifically in the middle (Uzbekistan, Armenia, Cuba, Brazil, Guatemala, Grenada, Mauritius, Kyrgyzstan, North Macedonia, Mexico, Romania, the Republic of Moldova, Saint Vincent, and the Grenadines) [27] and low-income countries (Bangladesh, Benin, Burkina Faso, Cambodia, Comoros, Eritrea, Liberia, Nepal, Rwanda, Tanzania, Togo, Uganda, and Zanzibar) [33]. To date, based on the statistics evidenced by the International Diabetes Federation (IDF), the estimated amount of people with DM raised from 108 million in 1980 [26] to 449 million in 2014 globally, and they predicted that this number will reach 702 million by 2045 [31, 34]. Currently, Asia (such as Afghanistan, Bangladesh, Bhutan, India, Maldives, Mauritius, Nepal, Pakistan, Sri Lanka, and China) has also emerged as the major area with a swiftly rising T2DM. In China, the prevalence of T2DM has rapidly increased by more than 140 million in 2021, and future projections suggest that this prevalence will be increased by over 174 million by 2045 [35]. Based on the report of the IDF (2019), after China, India, and the United States, Indonesia is predicted to have 21.3 million cases of DM in 2030 and be the fourth-largest country worldwide [36]. However, proper dietary management can reduce the risk of DM.

3. Nutritional Potentiality of Okara

In the present day, okara fulfills the dietary fiber and protein gap [37] as an alternative to the primarily plant-based dietary source of several kinds of cereals such as maize, wheat, and rice. Several studies have reported that the nutritional content of okara has offered various health benefits as a byproduct [38, 39]. Gabriel Quintana and his team reported that okara is a nutritionally valuable byproduct that is produced in big amounts during soymilk extraction [40].

The nutritional value of okara differs based on the cultivation process of soybean, soymilk processing method, and the content of water-soluble ingredients extracted from ground soybeans [41]. In addition, okara has a high content of moisture, approximately 70 to 80%. In a dry matter basis, 40% to 60% of fiber contains in the form of cellulose,

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

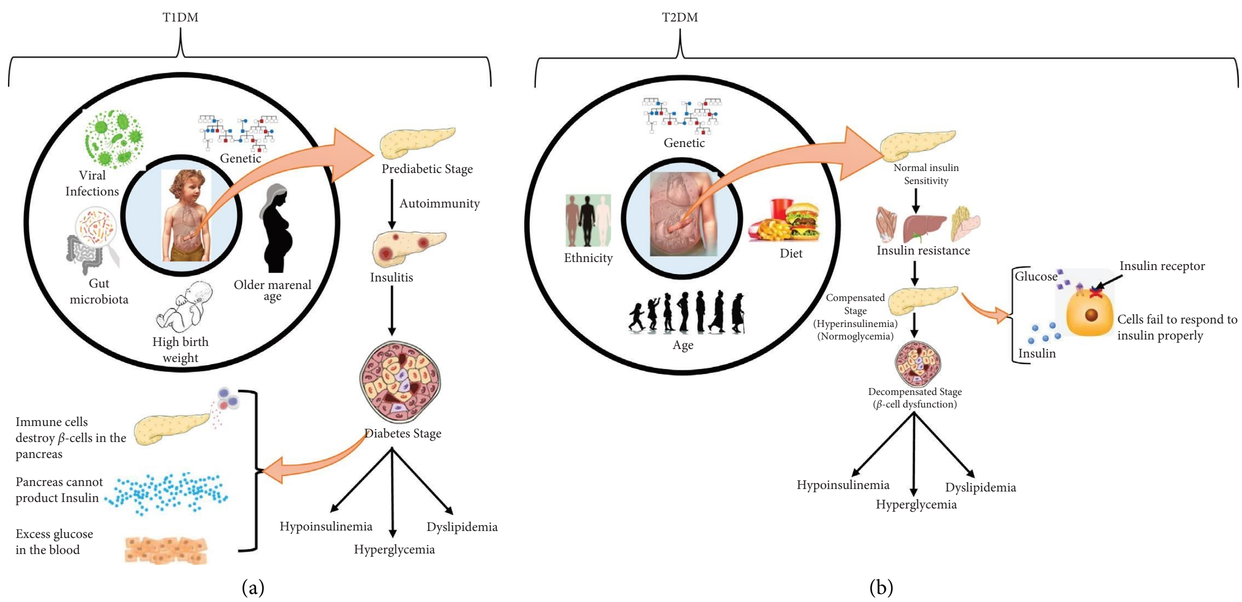

Figure 1: Diagram of T1DM (a) and T2DM (b). (a) The main causes of autoimmunity that contribute to the progression of T1DM with two leading stages, pediatric stage and diabetes stage. (b) T2DM normally starts with the passing from normal insulin sensitivity to insulin resistance, which in turn encourages the production and excretion of more insulin to manage normoglycemia culminating with decompensated stage.

hemicellulose, and carbohydrates (i.e., galactose, raffinose, arabinose, glucose, sucrose, fructose, and stachyose). Nutritionally, it also contains raffinose, stachyose, and mostly arabinose, glucose, galacturonic acid, galactose, fucose, and xylose, and a small quantity of rhamnose and mannose makes up the monomers in the cell walls of okara [41]. The nutritional value of food products (optimal range of okara flour added in food; dry weight basis (%)) is shown in Table 1.

3.1. Common Nutrients of Okara. Acquired from different processing methods (Figure 2), the nutritional value of okara may vary globally [10]. Liquid waste (LW) and okara can both be produced in large quantities by the soybean processing industry due to several steps of processing. Although it contains a large number of organic substances after the filtration, there still remains a significant amount of nutrients and high dietary fiber in okara due to its ruptured cotyledon cells and the external layer of the seed, which is rich in cell-wall polysaccharides. Okara has a variety of uses in food industries because of its several nutritional properties without any treatment; LW is normally discharged into the river [4]. Characterization of protein, fat, fiber, and mineral composition as well as unspecified monosaccharides and oligosaccharides in okara has been reported in the literature[50]. The composition of crude fiber, protein and amino acid content, isoflavones, lipid, crude ash, and minerals has been discussed in upcoming subsections.

3.1.1. Crude Fiber. Zhao et al. reported that okara is a good source of DF and can be fermented by bacteria in the large intestine but not in the small intestine [51]. It is evidenced that DF in okara can reduce blood pressure [52], decrease the level of blood cholesterol in some hyperlipidemic individuals [7], protect against chronic cardiac disease [19], prevent colon cancer, maintenance of normal bowel function, and regulate the level of blood sugar for diabetes [50].

According to Rahman et al., okara contains high fiber than soybean meal. It contains very high variable proportions of crude fiber along with a range of 12.1%–61.3% and neutral detergent fiber with a range of 12.7% to 72.6% on a DM basis. Soluble dietary fiber can be raised in okara using different treatment processes such as chemical treatment or enzymatic, fermentation, extrusion, and high pressure [4]. Before being consumed, the insoluble part of okara can be processed in a variety of ways to boost its nutritional content and flavor [10].

3.1.2. Protein and Amino Acid Content. Okara is a protein-enriched compound [2], particularly essential amino acids (EAA), but it has low solubility in water. It is documented that on a dry matter basis, okara is a significant source of affordable vegetable protein for human consumption since it has a protein content of about 27%, is highly nutritious, and has a remarkable protein efficiency ratio [53]. The protein in okara is of good quality than other soy products; for instance, the efficiency ratio is 2.71, whereas in soymilk is 2.11. However, the ratio of EAA to total amino acids (AA) is most similar to that of tofu. It is proved that the concentration of AA, compared to its unfermented competitors, has been found in fermented soybean, which has substantially higher protein content and more flavor [54].

Eze and his team illustrated the possible process to enhance okara's ability to extract protein [55]. From similar review papers, it has been identified that protein solubility in

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 1: Nutritional value of food products (optimal range of okara flour added in food; on a dry weight basis (%)).

Food products	Treatment/optimal range of okara flour added in food products (%)	Nutritional value (%)						
		Fiber	Protein	Carbohydrate	Fat	Moisture	Ash	Ref
Biscuits	40	7.25	15.35	56.6	13.25	6.3	1.25	[42]
Okara noodle	25	58.6	15.3	—	5.9	6.7	3.9	[43]
Butter cake	20	2.92	7.77	34.7	19.5	37.0	1.07	[44]
Biovalorised okara biscuits	20	10.35	8.62	—	19.11	—	1.09	[45]
Bread	10	0.14	9.74	—	3.10	37.74	1.97	[46]
Roti	30	17	30	—	9	28.5	5	[47]
Butter cake	20	7.84	28.67	—	14.35	4.74	4.27	[48]
Paratha	30	15	28	—	20	25.5	4.5	[47]

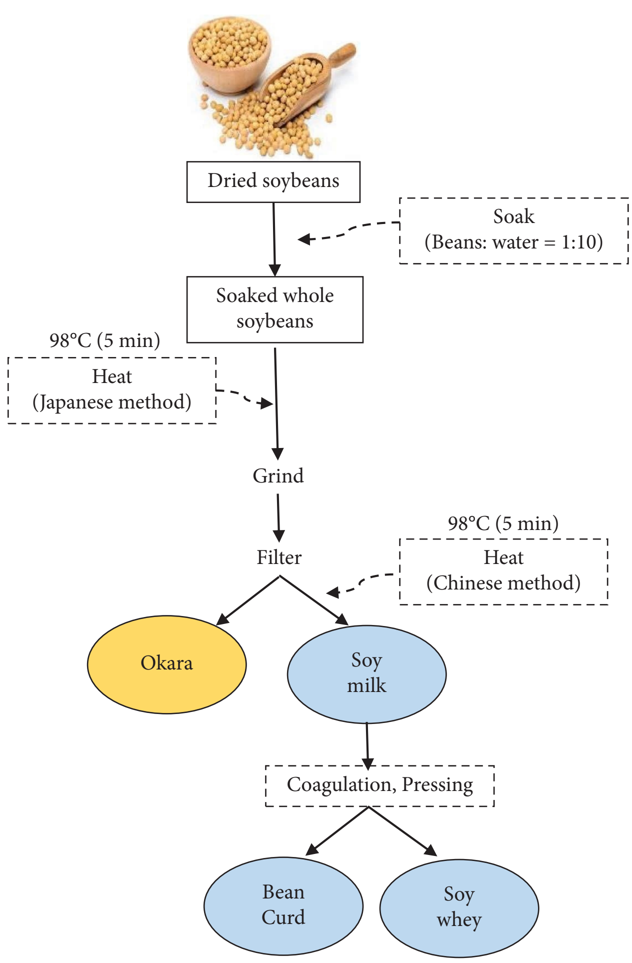

Figure 2: Japanese and Chinese extraction methods of okara from dried soybean [49]. The following stages are taken during the manufacturing of soymilk using the Chinese method: The process of processing soybean involves soaking, rinsing, grinding, heating, and filtering. The Japanese method, however, involves heating, grinding, and filtering soybean after it has been soaked, rinsed, and dried. The residual solid material after filtration is referred to as okara.

okara treated with acid is significantly increased, also other functional features, including foaming and emulsifying properties are being improved [53]. Okara can recover about 53% of the protein when extracted at pH 9.0 under 80°C for 30 minutes. The reason why okara proteins isolate was less soluble than soy protein isolate in both acidic and alkaline environments is most likely due to protein aggregation. According to a linked essay, the emulsification, fat binding, and foaming capabilities of protein from okara were shown to be comparatively better than commercial soy isolate. Soy peptides and free amino acids are produced during the fermentation of the okara protein. Therefore, there is a lot of potential for the development of protein resources from the okara [4, 50].

3.1.3. Isoflavones. Okara has an isoflavone content of 0.02 to 0.12 g/100 g solids or roughly 12% to 40% of the raw soybean isoflavones [56]. In addition to isoflavones (genistein and daidzein), lignans, saponins, phytosterols, coumestans, and phytates, okara is also likely to include other soy components including genistein and daidzein. These substances serve a variety of medicinal and physiological purposes [10]; for example, isoflavones control diabetes [57], affect resistance to carcinoma, prevent osteoporosis, reduce antibacterial inflammation, and control heart diseases. A major portion of the soybean isoflavones is left in okara during tofu processing [4, 14].

According to Jankowiak et al., during the manufacturing of soymilk, 12% to 30% of isoflavones are retained in okara. The main isoflavones in okara are 28.9% glucosides, 15.4% glycones, and a lower proportion of acetyl-genistin (0.89%) [58]. Li et al. clarified that approximately 4, 18, and 31% of the isoflavones, okara, and whey, respectively, were lost in the water during soaking the fresh soybeans [50]. A recent article reported that the total isoflavone content in acid-hydrolyzed okara flour was greater than in unhydrolyzed ones [41]. Some research indicated that producing isoflavone using fermented okara by microorganisms is comprehensive and mostly applicable to food industries and the pharmaceutical sector [50, 53].

3.1.4. Lipid. Okara contains a considerable quantity of lipids, around 8.3% to 10.9% on a dry matter basis [20]. The majority of fatty acids (FA) are monounsaturated or polyunsaturated, including linoleic acid (54.1% of total FA), palmitic acid (12.3%), oleic acid (20.4%), stearic acid (4.7%),

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

and linolenic acid (8.8%). Soy lipoxygenase and hydroperoxide lyase interact with the unsaturated fatty acids, especially linoleic acid, during soy bean grinding to produce fragrance compounds (i.e., hexyl, nonyl aldehydes, and alcohols). Low detection thresholds and these kinds of odorants are to blame for the off flavors in raw soymilk [59].

3.1.5. Crude Ash and Minerals. Okara contains crude ash of around 3.4 to 5.3% [53], a range of minerals with some amount of potassium (K), calcium (Ca), and iron (Fe) [60, 61], and the concentration of Ca is 0.26 to 0.43%. Marlina and Askar reported that the concentrations of phosphorus (P) and calcium (Ca) are approximately 0.6 and 0.7%, respectively, on a dry matter basis [4]. In contrast, Harthan and Cherney also documented that okara contains 2.3% of Ca and 4.6% of P [62]. Moreover, Dong et al. found that okara contains a greater Ca level of 1.2% than that in soybean meal around 0.4%, while soybean meal contains higher ash around 7.4% and 0.9% of P than in okara (4.3% and 0.9%, respectively) [4].

4. Mechanistic Insight of Soybean Bioactive Compounds and DM

Isoflavones (known as phytoestrogens), mainly daidzin and genistein found in okara, have been shown to lower serum blood glucose levels, promote metabolic activity, and inhibit adverse effects in diabetes (Figure 3) [63]. For decades, animal and epidemiological research has demonstrated the importance of soybean in diabetes prevention and glycemic control [64]. Isoflavones have also been proven to be useful in treating T2DM by reducing BGL owing to their ability to block the enzyme α-glucosidase [65]. Estrogen-related receptors (ERRs), which are nuclear receptors, are only activated by the peroxisome proliferator-activated receptor-gamma coactivator-1 beta (PGC-1β). In addition, it has been noted that isoflavones may have an antiobesity impact by activating the PGC-1/ERR pathway since genistein and daidzein act as ERR agonists [66]; hence, controlling obesity is interlinked with diabetes management [63, 67]. Intestinal α-glucosidase and pancreatic α-amylase are two major enzymes involved in starch digestion, resulting in glucose absorption in the liver. Bioactive substances that inhibit such enzymes can restrict the quantity of glucose in the blood by extending the release of glucose and thereby preventing hyperglycemia. The antiglycosidase activity of soybean was studied by Bai et al. in 2017, where they discovered that isoflavones and flavones include α-glycosidase inhibitors. The isoflavone and flavone content of the Glycine max extract is probably a reflection of their α-glucosidase inhibitory activity [68]. Emerging research revealed that soybean diets high in particular isoflavones, at least in part due to their soy peptides content, can have beneficial effects on multiple aspects of T2DM. Daidzein, for instance, is thought to be a useful treatment for diabetic retinopathy because it inhibits retinal neovascularization and has anti-inflammatory properties [64]. Hypocholesterolaemic soybean-derived peptides enhance glucose metabolism by promoting glucose absorption in a hepatic cell through glucose transporters type 1 and type 4. A serine exopeptidase called dipeptidyl peptidase-4 (DPP-4) is effectively inhibited by peptides found in soybean through *in vitro* and *in silico* studies, where DPP-4 triggers glucagon-like peptide hydrolysis and a glucose-dependent insulinotropic polypeptide that are essential for glucose homeostasis regulation [65]. Interestingly, several soybean peptides with hypolipidemic activity also have antidiabetic effects in various experimental models [63, 67]. Aspects of metabolic syndromes, such as insulin resistance, can be improved by dietary fiber via altering the gut flora [69]. Hyperlipidemia is often associated with T2DM and insulin resistance. Therefore, bioactive compounds with hypolipidemic activities can also exhibit antiobesity and antidiabetic activity [65].

5. Health Benefits of Okara as a Functional Food Ingredient on DM

There are many closely related definitions of functional food used globally. According to an EU document, “A food that beneficially affects one or more target functions in the body beyond adequate nutritional effects in a way that is relevant to either an improved state of health and wellbeing and/or reduction of risk of disease, it is consumed as part of a normal food pattern, it is not a pill, a capsule, or any form of dietary supplement” [70]. Some crucial functional food ingredients are soluble and insoluble DF, carotenoids, phenolic acids, phytoestrogens, fatty acids, flavonoids, prebiotics and probiotics, soy protein, vitamins, and minerals. Numerous pieces of evidence suggested that there is a strong relationship between functional food ingredients and potential health benefits. Functional food ingredients (okara) that are biologically active can lower the risk of some noncommunicable diseases including preventing diabetes and osteoporosis, cancer resistance, regulating heart disease, and decreasing antibacterial inflammation. Consumption of soy-containing foods has been reported to be linked with the prevention of cardiovascular syndrome, reduced blood cholesterol, reduced possibility of cancer (colon, breast, and prostate), osteoporosis, menopause symptoms, and cognitive function [34, 71–73]. Recently, it is reported that adequate intake of DF is advantageous for the treatment as well as prevention of T1DM and T2DM and improved diabetic dyslipidemia because it reduces body weight by postponing the digestion and absorption of carbs and increasing satiety; however, both mechanisms reduce postprandial hyperglycemia (Figure 4) [72, 73].

Nowadays, consumers are very aware of the benefits of DF, and most people believe that they intake enough fiber. National consumption surveys (NCSs) indicated that only 5% of the people meet recommendations, and inadequate consumption of DF has been called a public health concern [72]. Inadequate knowledge will affect the wrong diet, which eventually leads to raises in BGLs [25]. Therefore, nutrition and health educators can use communication techniques including providing clear and simple information, proposing flavorful fiber-enriched foods, and also emphasizing the advantages of adequate fiber consumption to help decrease the fiber intake gap [72].

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

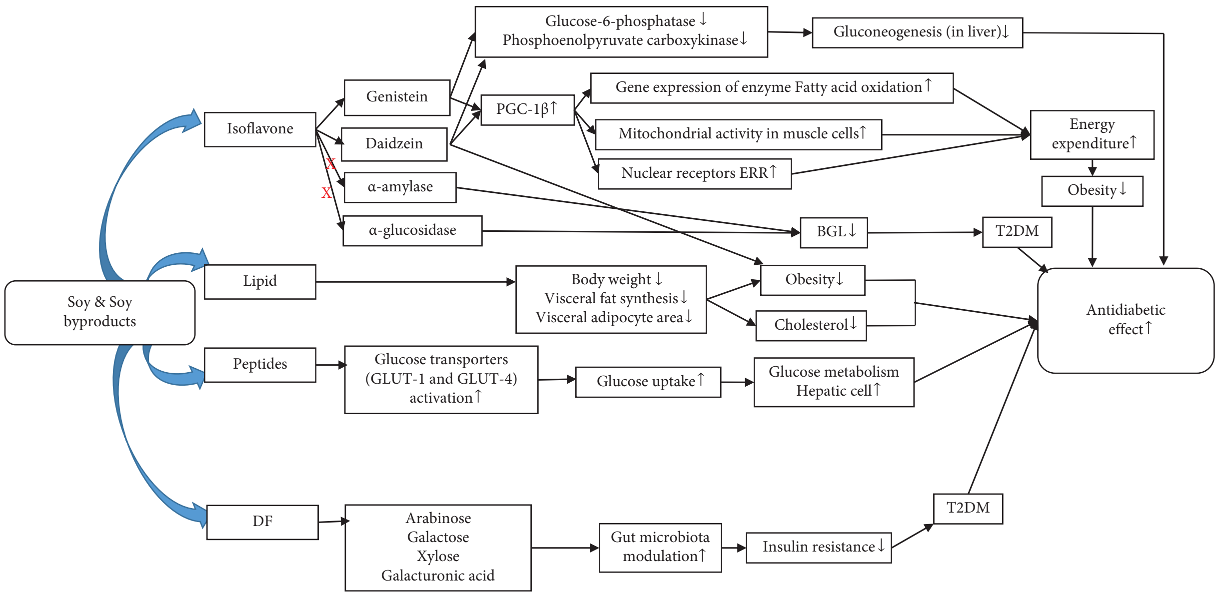

Figure 3: Soybean bioactive compounds and DM mechanism [63–69]. DF: dietary fiber, GLUT-1: glucose transporters type 1, GLUT-4: glucose transporters type 4, ERR: estrogen-related receptors, BGL: blood glucose level, ↓: decrease sign, ↑: increase sign, *X*: block sign, T2DM: type 2 diabetes mellitus, and PGC-1βvperoxisome proliferator-activated receptor-gamma coactivator-1 beta.

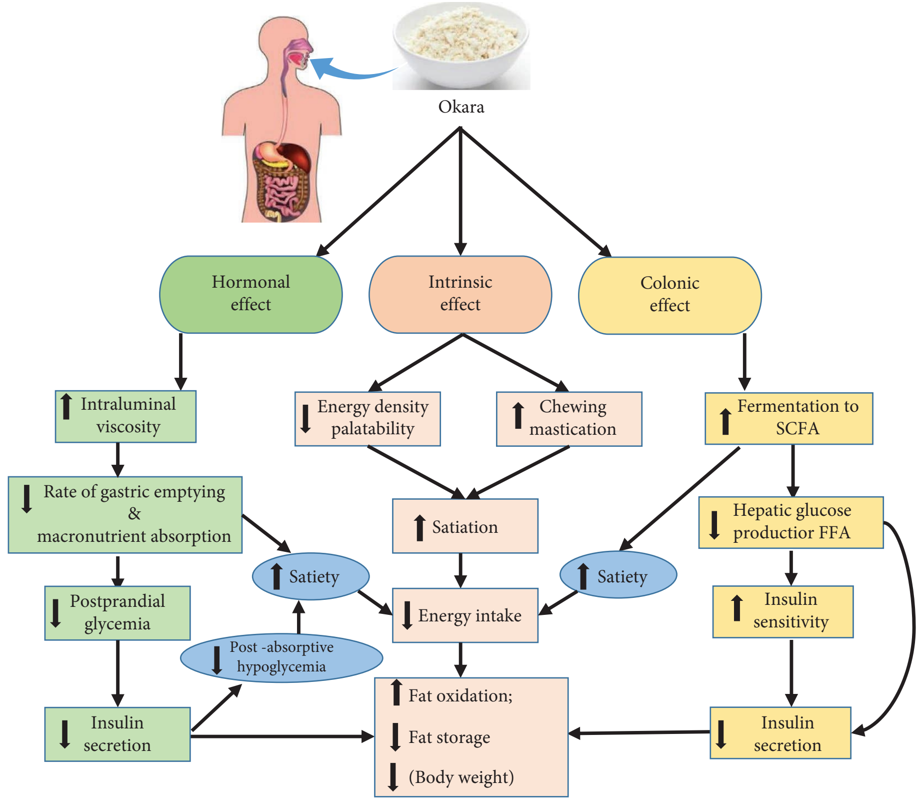

Figure 4: DF intake and developing DM [72, 73] (SCFA: short chain fatty acids; FFA: free fatty acids).

6. Okara, Dietary Fiber, and Diabetes Mellitus

Dietary fiber (DF) is known as a crucial dietary substance that's necessary for good health [74, 75]. "High DF-containing diets are associated with the prevention, reduction, and the treatment of some diseases" such as diabetes (Figure 5), coronary heart disease, and large intestine cancer [76, 77]. Increased consumption of DF reduces blood pressure and blood glucose levels, as well as reduces body weight [78]. Okara, a byproduct of soybean,

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

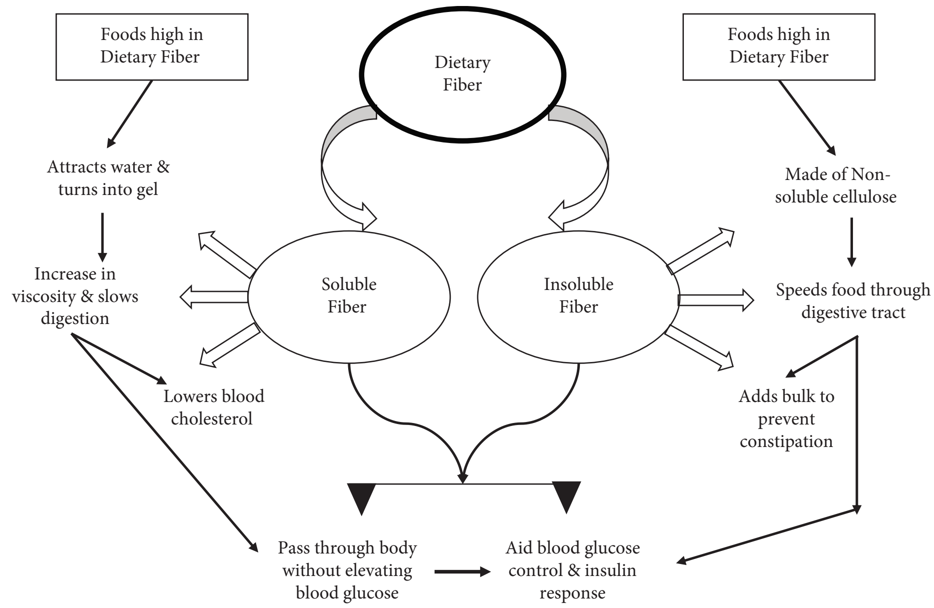

Figure 5: Dietary fiber consumption helps to manage diabetes.

has gained particular focus on health-beneficial effects as a fiber-rich (50% dietary fiber) food material that deals with diabetes to reduce blood glucose levels.

Much clinical research has documented the effect of dietary fiber- (DF-) enriched diets on patients with DM [22, 79, 79]. Hosokawa et al. reported that a healthy fiber diet can delay diabetic complications by controlling blood glucose levels. More recently, due to increased consumption of dietary fiber-containing food products to decrease insulin and blood glucose concentrations level, the functions of DF in the prevention of diabetes have received attention [80]. Xu et al. invented the effect of soy fiber on blood sugar, blood lipid metabolism, and hepatic nephritic histomorphology of mice along with streptozotocin-induced DM. Their study indicated that okara could markedly reduce the plasma levels of sugar and lipid, improve the metabolism of blood sugar and lipid, and also protect the liver and kidneys of DM mice [10].

7. DM and Dietary Patterns

Some risk factors are nonmodifiable or uncontrolled, such as age, gender, and genetics, and others can be modified or controlled such as unhealthy lifestyles with a low DF diet, irregular physical activity, and smoking. A diet with unhealthy and unbalanced foods and low DF is one of the vital causes of DM. For individuals with DM, the major challenging part of dietary management is to determine "what to eat." Multiple food intake patterns including vegetarian or vegan, Mediterranean style, DASH (Dietary Approaches to Stop Hypertension), low calorie, low fat, and high DF can be effective for achieving metabolic objectives for DM [28]. Research indicates that a high intake of fiber may reduce insulin resistance (IR) and the risk of developing T2DM [34, 81–83].

Some research studies showed that the Glycemic Index for okara steamed bread, okara bread, and okara noodle was low in level (referring to glucose GI = 100). They also proved that the GILs (glycemic Index level) of okara foods were distinctly lower than those of control foods (i.e., for bread 67 ± 3, noodles 77 ± 11, and steamed bread 86 ± 10) [10]. Numerous studies have indicated the importance of DF [10]. In several food industries, DF from different sources has been used to partially and/or completely replace cereal flour in the processing of bakery products to enhance the sensory characteristics of processed food products. It is possible to meet the criteria of high in DF and low in energy food products containing okara which is essential to the human body, especially for people with diabetes mellitus.

8. Recommendation of DF Intake

In the consumption of DF and functional fibers, there are many important health benefits, including preventing constipation, diabetes, obesity, and bowel problem, lower cholesterol, and avoiding colon and breast cancer. However, excessive DF consumption has some negative side effects, including dehydration (due to a fluid imbalance) and intestinal obstruction (in susceptible individuals), increases in intestinal gas that cause distention and flatulence, and has a decreased ability of the gut to absorb vitamins, proteins, calories, and minerals [10]. Thereby, it is very essential to maintain appropriate recommended DF intake for particular diseases.

So far, there is no toxicological report on tofu, soy products, or okara; hence, its application has been found safe. However, the Institute of Medicine (IOM) recommends DF intake depending on gender and age, which ranges from 19 to 38 g/day [72]. Based on Mogoș et al. recommendation of DF intake for the diabetic diet is from 35 to 40 g [84],

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

whereas approximately 75% of DM patients did not follow the suggested diet. DF intake is still below the advised range, with an average daily intake of 13.22 g of fiber. According to Abdurrachim and Annisa report, in Indonesia, for DM patients, the recommended dietary fiber intake is as much as 25 g/day [25]. The ADA recommends the consumption of a fiber-enriched diet that may help for secondary and tertiary prevention in patients with T2DM. DF has been explored as a treatment for DM for a long time because the foods with more fiber have lower glycemic index levels (GILs), which result in smaller spikes in blood glucose levels (BGLs) and lower blood glucose and HbA1c (hemoglobin A1c) levels [81]. In addition, the ADA has specific recommendations for DF consumption with diabetes. Furthermore, the recommended daily fiber intake for people with diabetes is 14 g of total fiber per 1000 kcal of energy, or around 25 g for adult females and 38 g for adult males [83]. Some observational studies have shown a negative correlation between total fiber consumption and DM [85].

9. Conclusion and Future Perspectives

The prevalence of diabetes is increasing worldwide, and T2DM is considered the most common type of diabetes, accounting for 90% of cases. Researchers working on diabetes suppose that the intake of large amounts of dietary fiber may help to control BGL after meals by slowing down the rate of carbohydrate absorption in the intestine. In addition, dietary fiber reduces triglyceride levels and blood cholesterol by binding to cholesterol and assisting in its excretion from the body. Moreover, patients with diabetes may benefit from a high-protein diet. Thus, okara is an ideal food for diabetics because it contains high levels of protein (25%) and dietary fiber about 50%.

However, due to its high moisture content, fresh okara decomposes quickly; hence, producers try to find quick and easy solutions to handle okara. In contrast, the majority of soymilk and tofu companies are dispersed and small-scale, making it challenging to collect a large quantity of okara for centralized processing if fresh okara cannot be dried as soon as feasible. So, to fully utilize okara, appropriate dryer development is still necessary [10]. In the food industry, there are insufficiently adequate food products that are enriched in functional food, linked to T2DM, so the intake of functional food such as okara should be stressed. There is also a future need to gain in-depth information about the therapeutic, nutraceutical, and safety prospects of this underutilized okara as a means to explore much of its health benefits to be used as a value-added ingredient in different food products [86]. Further, clinical research is also required to investigate the advantages of okara food products as a dietary nutrient, particularly in DM patients [65]. In addition, the multicomponent impacts of okara on biological activity are suggested for further analysis [86].

Data Availability

The data used to support the findings of this study are included in the article.

Additional Points

Highlights. (i) Diabetes mellitus is characterized by hyperglycemia which occurs due to abnormalities of insulin secretion by the pancreatic β-cells. (ii) Okara surprisingly receiving significant attention as health-beneficial effects for diabetes mellitus. (iii) The effect of consuming okara can reduce blood glucose levels.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

Kaisun Nesa Lesa and Nazir Ahmad participated in the study design and prepared the manuscript. Yunika Mayangsari and Faruque Mohammad Rashed Iqbal supervised and directed the project. Yunika Mayangsari, Mayeen Uddin Khandaker, Faruque Mohammad Rashed Iqbal, Dwi Larasatie Nur Fibri, and Md. Mehedi Hassan reviewed, edited, checked English grammar and corrected the final manuscript. All authors have read and approved the final manuscript.

References

[1] A. Asghar, M. Afzaal, F. Nosheen et al., "Isolation and molecular characterization of processed soybean waste for the development of synbiotic yogurt," *Fermentation*, vol. 8, pp. 1–12, 2022.

[2] M. F. Maria and A. E. Olaitan, "Effect of supplementing cassava with okara on biscuit quality," *Sumerianz Journal of Biotechnology*, vol. 3, pp. 99–105, 2020.

[3] A. Suzuki and J. Banna, "Improving diet quality for chronic disease prevention with okara "food waste," *American Journal of Lifestyle Medicine*, vol. 15, no. 1, pp. 14–18, 2021.

[4] M. M. Rahman, K. Mat, G. Ishigaki, and R. Akashi, "A review of okara (soybean curd residue) utilization as animal feed: nutritive value and animal performance aspects," *Animal Science Journal*, vol. 92, pp. 135944–e13616, 2021.

[5] L. T. Nguyen, T. H. Nguyen, L. T. Nguyen et al., "Okara improved blood glucose level in Vietnamese with type 2 diabetes mellitus," *Journal of Nutritional Science and Vitaminology*, vol. 65, no. 1, pp. 60–65, 2019.

[6] M. Faisal, A. Gani, F. Mulana, and H. Daimon, "Treatment and utilization of industrial tofu waste in Indonesia," *Asian Journal of Chemistry*, vol. 28, no. 3, pp. 501–507, 2016.

[7] X. Feng, H. Chen, Y. Liang et al., "Effects of electron beam irradiation treatment on the structural and functional properties of okara insoluble dietary fiber," *Journal of the Science of Food and Agriculture*, vol. 103, no. 1, pp. 195–204, 2023.

[8] D. B. Kamble and S. Rani, "Bioactive components, in vitro digestibility, microstructure and application of soybean residue (okara): a review," *Legume Science*, vol. 2, no. 1, p. e32, 2020.

[9] W. C. Vong and S. Q. Liu, "Changes in volatile profile of soybean residue (okara) upon solid-state fermentation by yeasts," *Journal of the Science of Food and Agriculture*, vol. 97, no. 1, pp. 135–143, 2017.

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

[10] B. Li, M. Qiao, and F. Lu, "Composition, nutrition, and utilization of okara (soybean residue)," *Food Reviews International*, vol. 28, no. 3, pp. 231–252, 2012.

[11] J. Y. Feng, R. Wang, K. Thakur et al., "Evolution of okara from waste to value added food ingredient: an account of its bio-valorization for improved nutritional and functional effects," *Trends in Food Science and Technology*, vol. 116, pp. 669–680, 2021.

[12] S. Singh, D. Kapoor, S. Bhardwaj et al., "4 microbial valorization of agri-waste," *Microbial Bioprocessing of Agri-Food Wastes: Bioactive Molecules*, CRC Press, Boca Raton, FL, USA, 2023.

[13] N. N. Nakornpanom, P. Hongsprabhas, and P. Hongsprabhas, "Effect of soy residue (okara) on in vitro protein digestibility and oil release in high-calorie emulsion stabilized by heated mixed proteins," *Food research international*, vol. 43, pp. 26–32, 2010.

[14] W. H. El-Reffaei, E. M. Ragheb, H. El-Ghandour, and S. E. Badr, "Nutritional and technological studies on using okara as by-product for fortified common foods falafel and biscuit," *Journal of Food and Dairy Sciences*, vol. 3, no. 9, pp. 481–506, 2012.

[15] M. Meenu, B. Padhan, J. Zhou et al., "A detailed review on quality parameters of functional noodles," *Food Reviews International*, pp. 1–37, 2022.

[16] Y. Hu, S. Wang, Z. Shi, L. Zhai, J. Fu, and J. Zhao, "Purification, characterization, and antioxidant activity of polysaccharides from Okara," *Journal of Food Processing and Preservation*, vol. 46, no. 3, Article ID e16411, 2022.

[17] V. Kumar, A. Rani, and L. Husain, "Investigations of amino acids profile, fatty acids composition, isoflavones content and antioxidative properties in Soy okara," *Asian Journal of Chemistry*, vol. 28, no. 4, pp. 903–906, 2016.

[18] H. Fan, Y. Zhang, M. S. Swallah et al., "Structural characteristics of insoluble dietary fiber from okara with different particle sizes and their prebiotic effects in rats fed high-fat diet," *Foods*, vol. 11, no. 9, p. 1298, 2022.

[19] Y. Huang, T. J. Ashaolu, and O. J. Olatunji, "Micronized dietary okara fiber: characterization, antioxidant, antihyperglycemic, antihyperlipidemic, and pancreato-protective effects in high fat diet/streptozotocin-induced diabetes mellitus," *ACS Omega*, vol. 7, no. 23, pp. 19764–19774, 2022.

[20] I. N. Ibrahim, N. A. Kamaruding, N. Ismail, and S. Shaharuddin, "Value addition to ice cream by fortification with okara and probiotic," *Journal of Food Processing and Preservation*, vol. 46, no. 2, Article ID e16253, 2022.

[21] S. K. Okyere, J. Wen, Y. Cui et al., "Bacillus toyonensis SAU-19 and SAU-20 isolated from Ageratina adenophora alleviates the intestinal structure and integrity damage associated with gut dysbiosis in mice fed high fat diet," *Frontiers in Microbiology*, vol. 13, Article ID 820236, 2022.

[22] L. Y. Chan, M. Takahashi, P. J. Lim et al., "Eurotium cristatum fermented okara as a potential food ingredient to combat diabetes," *Scientific Reports*, vol. 9, pp. 17536–17539, 2019.

[23] S. Han, Y. Luo, B. Liu, T. Guo, D. Qin, and F. Luo, "Dietary flavonoids prevent diabetes through epigenetic regulation: advance and challenge," *Critical Reviews in Food Science and Nutrition*, pp. 1–17, 2022.

[24] K. Topolska, A. Florkiewicz, and A. Filipiak-Florkiewicz, "Functional food—consumer motivations and expectations," *International Journal of Environmental Research and Public Health*, vol. 18, no. 10, p. 5327, 2021.

[25] R. Abdurrachim and R. D. Annisa, "Fiber intake and physical excercise contributed to blood glucose level in outpatients with type 2 diabetes mellitus," *Jurnal Gizi dan Dietetik Indonesia (Indonesian Journal of Nutrition and Dietetics)*, vol. 5, p. 66, 2018.

[26] W. L. Cataloguing, *Global Report on Diabetes*, vol. 978, World Health Organization, Geneva, Switzerland, 2016.

[27] N. Khaltaev and S. Axelrod, "Global trends in diabetes-related mortality with regard to lifestyle modifications, risk factors, and affordable management: a preliminary analysis," *Chronic Diseases and Translational Medicine*, vol. 7, no. 3, pp. 182–189, 2021.

[28] A. B. Evert, J. L. Boucher, M. Cypress et al., "Nutrition therapy recommendations for the management of adults with diabetes," *Diabetes Care*, vol. 37, no. Supplement_1, pp. 120–143, 2014.

[29] S. Singla, "Diabetes mellitus: etiology, prevalence and effects on quality of life of diabetic patients," *The Pharma Innovation Journal*, vol. 1925, pp. 1925–1933, 2022.

[30] M. Apostolakis, S. A. Paschou, E. Zapanti, V. Sarantopoulou, V. Vasileiou, and E. Anastasiou, "HbA1c presents low sensitivity as a post-pregnancy screening test for both diabetes and prediabetes in Greek women with history of gestational diabetes mellitus," *Hormones*, vol. 17, no. 2, pp. 255–259, 2018.

[31] X. Lin, Y. Xu, X. Pan et al., "Global, regional, and national burden and trend of diabetes in 195 countries and territories: an analysis from 1990 to 2025," *Scientific Reports*, vol. 10, pp. 14790–14811, 2020.

[32] D. J. Magliano, L. Chen, R. M. Islam et al., "Trends in the incidence of diagnosed diabetes: a multicountry analysis of aggregate data from 22 million diagnoses in high-income and middle-income settings," *Lancet Diabetes and Endocrinology*, vol. 9, no. 4, pp. 203–211, 2021.

[33] D. Flood, J. A. Seiglie, M. Dunn et al., "The state of diabetes treatment coverage in 55 low-income and middle-income countries: a cross-sectional study of nationally representative, individual-level data in 680 102 adults," *The Lancet Healthy Longevity*, vol. 2, no. 6, pp. e340–e351, 2021.

[34] F. Jin, J. Zhang, L. Shu, and W. Han, "Association of dietary fiber intake with newly-diagnosed type 2 diabetes mellitus in middle-aged Chinese population," *Nutrition Journal*, vol. 20, pp. 81–88, 2021.

[35] H. Sun, P. Saeedi, S. Karuranga et al., "IDF Diabetes Atlas: global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045," *Diabetes Research and Clinical Practice*, vol. 183, Article ID 109119, 2022.

[36] F. H. Arifah, A. E. Nugroho, A. Rohman, and W. Sujarwo, "A review of medicinal plants for the treatment of diabetes mellitus: the case of Indonesia," *South African Journal of Botany*, vol. 149, pp. 537–558, 2022.

[37] T. B. Ribeiro, G. B. Voss, M. C. Coelho, and M. E. Pintado, "Food waste and by-product valorization as an integrated approach with zero waste: future challenges," *Future foods*, pp. 569–596, 2022.

[38] T. Durman, L. S. de Lima, M. O. Rufino et al., "Feeding okara, a soybean by-product, to dairy cows as partial protein source enhances economic indexes and preserves milk quality, intake, and digestibility of nutrients," *Tropical Animal Health and Production*, vol. 54, pp. 14–17, 2022.

[39] D. P. Shan Lee, A. X. Gan, X. Xia et al., "Biovalorized okara consumption improves gut metabolites by modulating gut microbiome: a randomized controlled crossover trial," *Current Developments in Nutrition*, vol. 6, p. 1017, 2022.

[40] G. Quintana, E. Gerbino, and A. Gómez-Zavaglia, "Okara: a nutritionally valuable by-product able to stabilize

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

lactobacillus plantarum during freeze-drying, spray-drying, and storage," *Frontiers in Microbiology*, vol. 8, pp. 641–649, 2017.

[41] W. C. Vong and S. Q. Liu, "Biovalorisation of okara (soybean residue) for food and nutrition," *Trends in Food Science and Technology*, vol. 52, pp. 139–147, 2016.

[42] A. Hawa, N. Satheesh, and D. Kumela, "Nutritional and antinutritional evaluation of cookies prepared from okara, red teff and wheat flours," *International Food Research Journal*, vol. 25, pp. 2042–2050, 2018.

[43] F. Lu, Z. Cui, Y. Liu, and B. Li, "The effect of okara on the qualities of noodle and steamed bread," *Advance Journal of Food Science and Technology*, vol. 5, no. 7, pp. 960–968, 2013.

[44] H. Nguyen Doan Mai, K. Phan Thi Lan, C. Techapun et al., "Quality evaluation of butter cake prepared by substitution of wheat flour with green soybean (Glycine Max L.) okara," *Journal of Culinary Science and Technology*, vol. 21, no. 4, pp. 606–619, 2021.

[45] D. P. S. Lee, A. X. Gan, and J. E. Kim, "Incorporation of biovalorised okara in biscuits: improvements of nutritional, antioxidant, physical, and sensory properties," *Lebensmittel-Wissenschaft and Technologie*, vol. 134, Article ID 109902, 2020.

[46] G. L. Wickramarathna and P. C. Arampath, "Utilization of okara in bread making," *Journal of Science*, vol. 31, pp. 29–33, 2003.

[47] S. Afrin Zinia, A. Rahim, M. Latif Jony, A. Ara Begum, and M. Rahman Mazumder, "The roles of okara powder on the processing and nutrient content of roti and paratha," *International Journal of Agriculture and Environmental Science*, vol. 6, no. 2, pp. 18–23, 2019.

[48] H. Nguyen Doan Mai, K. Phan Thi Lan, C. Techapun et al., "Quality evaluation of butter cake prepared by substitution of wheat flour with green soybean (Glycine max L.) okara," *Journal of Culinary Science and Technology*, vol. 21, no. 4, pp. 606–619, 2021.

[49] A. Asghar, M. Afzaal, F. Saeed et al., "Valorization and food applications of okara (soybean residue): a concurrent review," *Food Science and Nutrition*, vol. 11, no. 7, pp. 3631–3640, 2023.

[50] S. Li, D. Zhu, K. Li, Y. Yang, Z. Lei, and Z. Zhang, "Soybean curd residue: composition, utilization, and related limiting factors," *ISRN Industrial Engineering*, vol. 2013, Article ID 423590, 8 pages, 2013.

[51] L. Zhao, J. Wu, Y. Liu, H. Wang, and C. Cao, "Effect of Lactobacillus rhamnosus GG fermentation on the structural and functional properties of dietary fiber in bamboo shoot and its application in bread," *Journal of Food Biochemistry*, vol. 46, no. 9, Article ID e14231, 2022.

[52] H. Xie, X. Tang, M. W. Woo, H. Xiong, and Q. Zhao, "Effects of enzymatic/alkali protein removal and particle size reduction on physicochemical and functional characteristics of okara dietary fibre," *International Journal of Food Science and Technology*, vol. 57, no. 5, pp. 3171–3180, 2022.

[53] W. C. Vong and S. Q. Liu, "Biovalorisation of okara (soybean residue) for food and nutrition," *Trends in Food Science and Technology*, vol. 52, pp. 139–147, 2016.

[54] D. K. O'Toole, "Characteristics and use of okara, the soybean residue from soy milk production- a review," *Journal of Agricultural and Food Chemistry*, vol. 47, no. 2, pp. 363–371, 1999.

[55] O. F. Eze, A. Chatzifragkou, and D. Charalampopoulos, "Properties of protein isolates extracted by ultrasonication from soybean residue (okara)," *Food Chemistry*, vol. 368, Article ID 130837, 2022.

[56] M. M. Muliterno, D. Rodrigues, F. S. de Lima, E. I. Ida, and L. E. Kurozawa, "Conversion/degradation of isoflavones and color alterations during the drying of okara," *Lebensmittel-Wissenschaft and Technologie*, vol. 75, pp. 512–519, 2017.

[57] K. C. Duru, E. G. Kovaleva, I. G. Danilova, P. Van der Bijl, and A. V. Belousova, "The potential beneficial role of isoflavones in type 2 diabetes mellitus," *Nutrition Research*, vol. 59, pp. 1–15, 2018.

[58] L. Jankowiak, O. Trifunovic, R. M. Boom, and A. J. van der Goot, "The potential of crude okara for isoflavone production," *Journal of Food Engineering*, vol. 124, pp. 166–172, 2014.

[59] A. Colletti, A. Attrovio, L. Boffa, S. Mantegna, and G. Cravotto, "Valorisation of by-products from soybean (Glycine max (L.) merr.) processing," *Molecules*, vol. 25, no. 9, p. 2129, 2020.

[60] I. Mateos-Aparicio, C. Mateos-Peinado, A. Jiménez-Escrig, and P. Rupérez, "Multifunctional antioxidant activity of polysaccharide fractions from the soybean byproduct okara," *Carbohydrate Polymers*, vol. 82, no. 2, pp. 245–250, 2010.

[61] S. P. Stanojevic, M. B. Barac, M. B. Pesic, V. S. Jankovic, and B. V. Vucelic-Radovic, "Bioactive proteins and energy value of okara as a byproduct in hydrothermal processing of soy milk," *Journal of Agricultural and Food Chemistry*, vol. 61, no. 38, pp. 9210–9219, 2013.

[62] L. B. Harthan and D. J. Cherney, "Okara as a protein supplement affects feed intake and milk composition of ewes and growth performance of lambs," *Animal Nutrition*, vol. 3, no. 2, pp. 171–174, 2017.

[63] S. H. Nile, B. Venkidasamy, R. Samynathan et al., "Soybean processing wastes: novel insights on their production, extraction of isoflavones, and their therapeutic properties," *Journal of Agricultural and Food Chemistry*, vol. 70, no. 23, pp. 6849–6863, 2022.

[64] J. S. Cai, J. Y. Feng, Z. J. Ni et al., "An update on the nutritional, functional, sensory characteristics of soy products, and applications of new processing strategies," *Trends in Food Science and Technology*, vol. 112, pp. 676–689, 2021.

[65] M. S. Swallah, X. Yang, J. Li et al., "The pros and cons of soybean bioactive compounds: an overview," *Food Reviews International*, pp. 1–28, 2022.

[66] S. Nakai, M. Fujita, and Y. Kamei, "Health promotion effects of soy isoflavones," *Journal of Nutritional Science and Vitaminology*, vol. 66, no. 6, pp. 502–507, 2020.

[67] C. Chatterjee, S. Gleddie, and C. W. Xiao, "Soybean bioactive peptides and their functional properties," *Nutrients*, vol. 10, no. 9, p. 1211, 2018.

[68] M. Kumar, R. Suhag, M. Hasan et al., "Black soybean (Glycine max (L.) Merr.): paving the way toward new nutraceutical," *Critical Reviews in Food Science and Nutrition*, pp. 1–27, 2022.

[69] J. Zou, L. Reddivari, Z. Shi et al., "Inulin fermentable fiber ameliorates type I diabetes via IL22 and short-chain fatty acids in experimental models," *Cellular and Molecular Gastroenterology and Hepatology*, vol. 12, no. 3, pp. 983–1000, 2021.

[70] R. John and A. Singla, "Functional Foods: components, health benefits, challenges, and major projects," *DRC Sustainable Future*, pp. 61–72, 2021.

[71] S. Li, D. Zhu, K. Li, Y. Yang, Z. Lei, and Z. Zhang, "Soybean curd residue: composition, utilization, and related limiting factors," *ISRN Industrial Engineering*, vol. 2013, Article ID 423590, 8 pages, 2013.

[72] D. Quagliani and P. Felt-Gunderson, "Closing America's fiber intake gap: communication strategies from a food and fiber

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

summit," *American Journal of Lifestyle Medicine*, vol. 11, no. 1, pp. 80–85, 2017.
[73] M. Chandalia, A. Garg, D. Lutjohann, K. von Bergmann, S. M. Grundy, and L. J. Brinkley, "Beneficial effects of high dietary fiber intake in patients with type 2 diabetes mellitus," *New England Journal of Medicine*, vol. 342, no. 19, pp. 1392–1398, 2000.
[74] D. M. Lebesi and C. Tzia, "Effect of the addition of different dietary fiber and edible cereal bran sources on the baking and sensory characteristics of cupcakes," *Food and Bioprocess Technology*, vol. 4, no. 5, pp. 710–722, 2011.
[75] T. M. Barber, S. Kabisch, A. F. Pfeiffer, and M. O. Weickert, "The health benefits of dietary fibre," *Nutrients*, vol. 12, no. 10, p. 3209, 2020.
[76] F. Figuerola, M. L. Hurtado, A. M. Estévez, I. Chiffelle, and F. Asenjo, "Fibre concentrates from apple pomace and citrus peel as potential fibre sources for food enrichment," *Food Chemistry*, vol. 91, no. 3, pp. 395–401, 2005.
[77] S. Gupta, J. J. Lee, and W. N. Chen, "Analysis of improved nutritional composition of potential functional food (okara) after probiotic solid-state fermentation," *Journal of Agricultural and Food Chemistry*, vol. 66, no. 21, pp. 5373–5381, 2018.
[78] J. W. Anderson, P. Baird, R. H. Davis Jr et al., "Health benefits of dietary fiber," *Nutrition Reviews*, vol. 67, no. 4, pp. 188–205, 2009.
[79] M. Hosokawa, M. Katsukawa, H. Tanaka et al., "Okara ameliorates glucose tolerance in GK rats," *Journal of Clinical Biochemistry and Nutrition*, vol. 58, no. 3, pp. 216–222, 2016.
[80] S. P. Whelton, A. D. Hyre, B. Pedersen, Y. Yi, P. K. Whelton, and J. He, "Effect of dietary fiber intake on blood pressure: a meta-analysis of randomized, controlled clinical trials," *Journal of Hypertension*, vol. 23, no. 3, pp. 475–481, 2005.
[81] R. E. Post, A. G. Mainous, D. E. King, and K. N. Simpson, "Dietary fiber for the treatment of type 2 diabetes mellitus: a meta-analysis," *The Journal of the American Board of Family Medicine*, vol. 25, no. 1, pp. 16–23, 2012.
[82] B. Yao, H. Fang, W. Xu et al., "Dietary fiber intake and risk of type 2 diabetes: a dose-response analysis of prospective studies," *European Journal of Epidemiology*, vol. 29, pp. 79–88, 2014.
[83] M. O. Weickert and A. F. Pfeiffer, "Impact of dietary fiber consumption on insulin resistance and the prevention of type 2 diabetes," *Journal of Nutrition*, vol. 148, no. 1, pp. 7–12, 2018.
[84] T. Mogoş, C. Dondoi, and A. E. Iacobini, "A review of dietary fiber in the diabetic diet," *Romanian Journal of Diabetes Nutrition and Metabolic Diseases*, vol. 24, no. 2, pp. 161–164, 2017.
[85] M. V. Beretta, F. R. Bernaud, C. Nascimento, T. Steemburgo, and T. C. Rodrigues, "Higher fiber intake is associated with lower blood pressure levels in patients with type 1 diabetes," *Archives of Endocrinology and Metabolism*, vol. 62, pp. 47–54, 2018.
[86] G. Dukariya, S. Shah, G. Singh, and A. Kumar, "Soybean and its products: nutritional and health benefits," *Journal of Nutritional Science and Healthy Diet*, vol. 1, pp. 22–29, 2020.

6095, 2023, 1, Downloaded from https://onlinelibrary.wiley.com/doi/10.1155/2023/5540118 by Nat Prov Indonesia, Wiley Online Library on [19/08/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License