Chapter

Nutritional Interventions: Diet Modifications, Nutritional Supplements, Complementary and Alternative Medicine

Jameela Banu

Abstract

Type 2 diabetes (T2DM) is characterized by increased circulating blood glucose levels. Several therapies are available to control glucose levels. However, nutritional choices play a major role in managing diabetes. Nutritional supplements can help in reducing the side effects of medicines on the individual so, this chapter will not only discuss several nutritional choices but also available nutritional supplements to control T2DM. Keeping in mind the traditional belief that food is medicine and as therapies are often associated with deleterious side effects, this chapter will discuss alternative and herbal medicines. In addition, life style alterations with proper nutritional choices is also important and will be touched upon in this chapter.

Keywords: diet modifications, nutritional supplements, complementary and alternative medicine

1. Introduction

Diabetes Mellitus (DM) is a chronic metabolic medical condition that is diagnosed in 422 million people globally and every year 1.6 million deaths are attributed to this condition [1]. It is a disease that can lead to many other severe medical problems and affects almost all the different systems in the body. Diabetes as a result of autoimmune condition, where the pancreatic β-cells are destroyed compromising insulin production, is referred to as Type 1 Diabetes Mellitus (T1DM), while diabetes caused by several other factors including increasing insulin resistance is referred to as Type 2 Diabetes Mellitus (T2DM). As the classic symptom of diabetes is increase in circulating blood glucose, one of the important treatment criteria is focused on food consumption and the type of nutrients consumed. Several diets have been advocated to patients, in addition to life style changes such as increased physical activity and an organized exercise regimen. As carbohydrates are the main source of glucose, diets closely look at reducing carbohydrate intake followed by fat consumption. A major risk factor for developing diabetes is being obese. So many diet plans for diabetic patients focus on weight loss. We will discuss the different diets, nutritional supplements and any alternative and complementary medical choices the patients can opt for.

2. Diets

Several diets have been available for patients with diabetes. Some of them are tested in randomized clinical trials while others have been put forth by nutritionists or other professionals. The main focus of these diets is weight loss as obesity is also a growing global pandemic and is a major risk factor for several severe medical conditions including T2DM. Large randomized controlled studies such as Look Action for Health in Diabetes (Look AHEAD) study, Finnish Diabetes Prevention study and Diabetes Prevention Program Research group had focused on reducing body weight and incidence of diabetes.

2.1 Look AHEAD study

This study included 5145 patients and continued for eleven years (2001–2012) in the US [2]. The major goals for this study were to reduce body weight by 7% and increasing physical activity to ≥175 mins/week. Participants of this study were ethnically diverse (African Americans, Hispanic and Native American/Alaskan native) and were diabetic. Co morbidities included hypertension and cardiovascular disease (CVD) [2]. There were three phases of the study with nutritional interventions, lifestyle and behavioral modifications. The nutritional interventions were as follows: Phase I (1–12 months) patients were encouraged to replace two of their meals with shakes, one snack with a bar and consume low energy dense foods. The energy goals were dependent on the body weight of the individuals: <250 lbs. were limited to 1200-1500Kcal and those ≥250 lbs. were limited to 1500-1800 kcal/day [2]. Medications were given to patients who failed to show weight reduction in the first 6 months. Physical activity goals were set at moderately intense activity for 175 minutes/week. Either self monitoring or in person monitoring was conducted at regular intervals. Weight regain was addressed by further counseling and replanning the diet. In Phase 2 (2 years –4 years) and Phase 3 (5 years and above) patients were monitored and were expected to maintain the goal of 10% body weight loss following the diet and activity [2]. Patients successfully lost weight and were physically fit with this diet lifestyle change, however, they could not maintain the weight loss [3]. Patients also improved some of the conditions for diabetic patients [3].

2.2 Finnish diabetes prevention study

This study was started in 1998 to determine if an intensive exercise-diet program can prevent or delay the onset of T2DM [4]. A total of 522 patients were in the study and divided into the control and intervention groups. The diet modification included reduction of total fat consumption to <30% with less than 10% saturated fats and high fiber intake [4]. The physical activity goal was 4 hours/week of walking, bicycling or other exercise [5]. The focus of this study was to follow patients to see if there was decrease in the development of diabetes and reported that there was 43% decrease in the risk of development of diabetes. After thirteen years, this study reported that the recommended interventions successfully prevented the progression of T2DM on a long term basis [6].

2.3 Diabetic prevention program research group

This study was conducted across 27 clinics in the US. There were 1079 ethnically diverse patients [7]. The goal was to reduce body weight by 7% in the first 6 months by increasing physical activity and consuming a diet with less fats and saturated fats. They reported a 58% reduction in the incidence rate of diabetes [7].

Other long term randomized clinical trials like Da Qing IGT and Diabetes Study have also shown that diet and exercise interventions are very efficient in reducing the risk of developing diabetes [8].

2.4 Low carbohydrate diet

The recommended intake of carbohydrate is 45% - 65% per day. Choices with decreased refined carbohydrates, no added sugar, increased intake of grains, legumes, vegetables and fruits were recommended along with limiting high fructose syrup and sucrose. The sources of carbohydrates are not a major factor in the glycemic response as randomized trials showed no difference in glycemic response when sources of carbohydrates was substituted [9]. However, it is important to note that complex sources of carbohydrates are beneficial in determining the circulating glucose levels after meals. Post prandial glucose levels are reflective of the amount of sugar not the type of sugar [10, 11]. Fructose is metabolized in the liver and can affect lipid metabolism so limiting fructose consumption is recommended. Low carbohydrate diet is very effective in decreasing body weight [12, 13]. Patients on this diet not only lost body weight but also decreased HbA1C, however, they were prone to gain weight very quickly. Low carbohydrate diet maybe a short term solution to manage T2DM and can comprise of fiber, vitamins and minerals. Patients on such diet have to be checked for their lipid profile, renal function and protein intake regularly [14].

2.5 Low glycemic index diet

Glycemic Index (GI) rises with increase in glucose levels [10]. Factors affecting GI are rate of digestion, cooking method, type of carbohydrate, fat content, protein content and acidity of the food. High starchy foods digest faster so there is high and quick release of glucose. Lower GI foods does not rise the blood glucose levels as quickly. Insulin response and glucagon inhibitors are also affected. High fiber delays the digestion process, increases CCK, incretins and satiety. Lower glycemic diet does not reduce body weight but reduces HbA1c and improves insulin sensitivity [15, 16]. This diet can only have moderate effects in controlling postprandial hyperglycemia. It did not have any effect on the body weight but decreased HbA1C by 0.5% [10].

2.6 Low fat diet

Fat consumption is targeted by this diet as diets high in fats can reduce insulin sensitivity and increase endogenous production of glucose by the liver and production of proinflammatory cytokines [10, 17]. This diet focuses more on consumption of ≤30% calories from fat which would be around 50 g of fat for 1500Kcal/day diet. The type of fat consumed determines the damage caused more than the quantity of fat especially with respect to glycemic control [18]. It induced weight loss and had very little effect on glycemic control [10]. However, the long term effects of weight loss may reduce or delay the onset of T2DM.

2.7 Very low calorie diet

Decreasing calories is another method to reduce body weight, thereby, decreasing the risk of developing T2DM. The recommendation for those seeking this diet option consumed 400 to 800 calories/d of high quality protein and carbohydrates fortified with vitamins, minerals and trace elements. Decreased body weight and HbA1C were reported with high rate of body weight regain [10].

2.8 Mediterranean diet

This diet is more popular and 30–40% of the diet consists of monounsaturated fats. Legumes, fruits, vegetables, nuts, whole grain, fish and moderate ingestion of wine. Has a positive effect on glycemic control and reduces the incidence of diabetes by 52% (**Figure 1**). The body weight regain with this diet was low. The major problem is that adherence rate was low [10].

2.9 Protein sparing modified diet

Combination of low carbohydrate ketogenic diet and very low calorie diet. Patients prescribed this diet are started off on a very low calorie diet (800 calories/day) for the first six months and then the calories are increased gradually. At the beginning carbohydrate intake is limited to 20-50 g/day with 1.2–1.5 g/Kg of proteins [19]. Successful in weight loss and lowering HbA1C and fasting glucose. However, there is a low adherence rate among patients and they may increase weight regain quickly [10].

2.10 Vegetarian and vegan diet

Both vegetarian and vegan diets are centered around cereal, fruits, vegetables, legume and nuts. However, vegetarian diets may include dairy products and/or

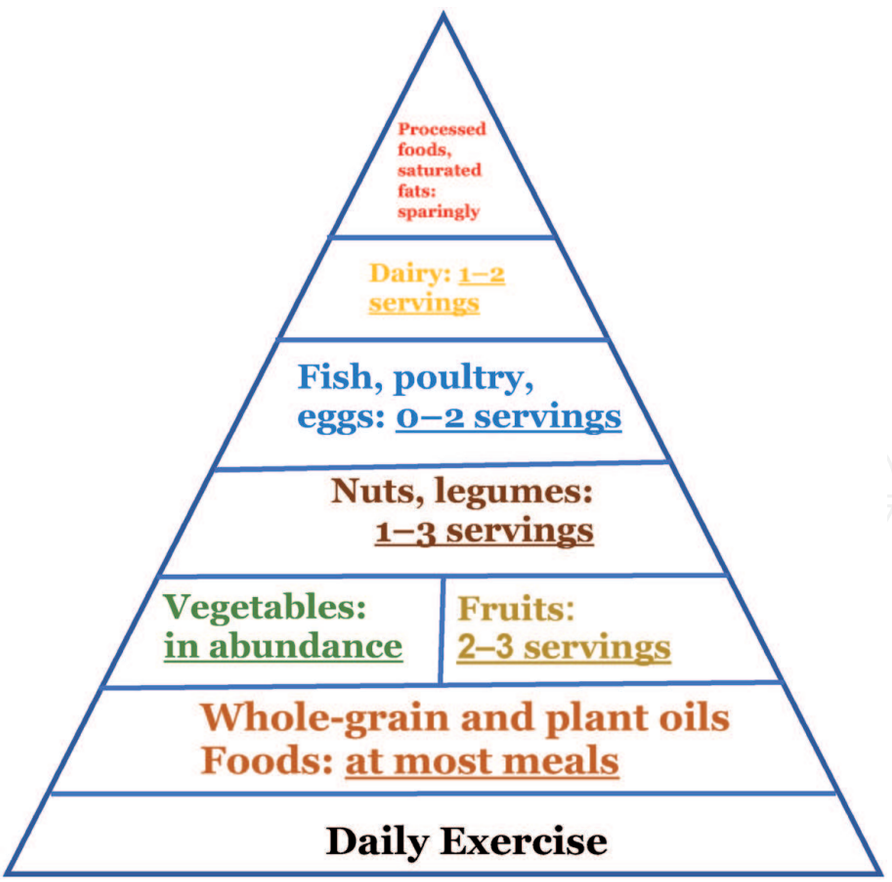

Figure 1.
Mediterranean diet: Recommends consumption of mainly whole grains, vegetables, fruits, nuts and legumes. Limiting animal protein to 0–2 servings and one serving of dairy (as a source of calcium). Consumption of red meat, saturated fats and processed foods is not encouraged and recommended to consume only sparingly. Moderate consumption of wine is now recognized as part of this diet.

eggs. It reduced body weight, but reduction of HbA1C was not significant. There is very little research on the long term effects of these diets. And it is known that patients on these diets may lack in essential nutrients [10].

2.11 High protein diet

A major portion of the calories in this diet is protein with 30% of energy from proteins. Weight loss occurred with females losing total fat and abdominal fat mass. But total lean mass also decreased. Although it improved glucose control and decreased HbA1C (0.28%) [20]. Low fat cottage cheese, cheese tofu, red meat, chicken, peanut butter, fish and lentils were some of the constituents of this diet. Diet should be individualized and patients must account for cardiometabolic risk and renal profile, long term effects are not known [10].

2.12 Other diets

Based on the knowledge about the effects of different macronutrients on circulating glucose levels many other popular diets have been introduced. These diets have not been studied using controlled trials so the outcomes are not authenticated. These diets include the Paleo diet, Atkins diet/keto diet, Nutrisystems etc. They are all focused on weight loss. It is important to account for the different macro and micronutrients on maintaining normal metabolism in the body. Therefore, a carbohydrate free or a fat free diet or vegan diet can be very deleterious to health, unless there is a balance in the nutrient intake.

2.12.1 Paleo diet

Paleo diet also referred to as the Hunter-Gatherer diet or Stone Age diet became popular as the evolution of human diets was recognized from simple diets to complex highly processed diets in the modern world. The Paleo diet simulates diet eaten by the Stone Age humans who were hunters and collected food that was readily available in nature like meat (mainly lean), organ meats, fish, vegetables, fruits, nuts and seeds [21]. This diet is reported to improve insulin resistance and showed significant decrease in HbA1C, body weight and BMI is a small clinical trial [22, 23]. The main issues with this diet is that patients have low vitamin D and calcium [24].

2.12.2 Atkins/keto diet

The Atkins diet was promoted by Dr. Robert C Atkins, a cardiologist and recommended a low carbohydrate with high protein and fat diet. There are several modifications now available and are referred to as Keto diet. This diet shifts the energy needs of the body from carbohydrate to fats, therefore, The diet includes sources of high fat content like butter, nuts and cream [25]. The low carbohydrate diet recommends the use of 100 g/d of carbohydrates with 50–60% fat and 20–30% protein and the very low carbohydrate diet recommends <50 g/d of carbohydrates. Weight loss, low insulin levels, deceased hunger are some of the benefits reported [26, 27]. In T1DM patients the carbohydrate levels have to be adjusted to the insulin levels to maintain post prandial glucose levels and reduce hypoglycemia [28]. The preferred source of energy in the body is glucose, restricting this macronutrient forces the body to use fats for energy production. Unfortunately, when this happens many ketone bodies are produced and this is deleterious to the metabolism especially in the long run.

2.12.3 Nutrisystems

A meal plan for losing weight was proposed by Nutrisystems. This diet is customized to individuals for three meals and snacks per day. These diets are balanced and claims to be easy to prepare. The foods used are low glycemic carbohydrates, high fiber and lean proteins with no artificial sweeteners or flavors. Customers are expected to pick from basic, vegetarian, uniquely your, uniquely your ultimate, basic diabetss, diabetes-uniquely yours, ultimate diabetes as well as diet for men. Customers are given the option of picking their own meals or from customized meals. A couple of small (10 and 69 participants) short term (three months) studies used a portion controlled Nutrisystem diabetic diet to determine the effects on weight loss and diabetes. They reported that obese T2DM patients may show significant improvements in weight and glycemic control [29, 30]. A slightly larger study (100 participants) conducted for six months using Nutrisystem diabetes diet reported significantly increased weight loss with statistically insignificant reduction of HbA1C [31]. As this diet is more flexible than the other diets, it may be beneficial to individuals who carefully adhere to the diet and instructions.

Many other modified diets such as South Beach Diet, Zone diet, Macrobiotics, Blood group diet, Ayurvedic diets, Raw food diets, Cleansing diet, Crash diets, Calorie restricted diet are also available. These diets focus on reducing body weight and the major recommendations include decreased or no processed foods, more fiber, vegetables and fruits and decreased total fat intake [32, 33]. Care has to be taken to avoid any vitamins and mineral deficiencies.

3. Nutritional supplements

The use of natural products as therapy was in practice for many centuries in different parts of the world. This practice relates very well with the idea that food is medicine. Some of these practices are classified as traditional medicine. Around the world there is an increase interest in using these medicines which are categorized under complementary and alternative medicines. In developing countries, 90% of the population seek plant products as alternative treatment options [34]. The most important benefit could be that there are less or even no side effects and is cost effective. However, the main constraint for these products not being popularly recommended, is the limited scientific evidence about the efficacy, mechanism and side effects. But this is slowly changing as in the past few decades, scientific literature with information on the efficacy, side effects and mechanism of action of several natural products and their compounds has increased. Some of these different natural products that are not only implicated in controlling diabetes but also decrease other medical complications that arise due to diabetes [35].

Plant products are unique in that they have several ingredients and the active ingredient(s)/compound(s) are attributed to having the main effect. This has led the pharmaceutical industry to use some of these active ingredients in currently available allopathic drugs [36]. It is important to identify these active ingredients and study their effects to understand their mechanisms of action. However, it has been observed that when these compounds are isolated, they are sometimes not as efficient when compared to the whole extracts and this maybe because the other ingredients, although in small quantities, may influence the activity of the main compound.

High blood glucose can be due to several different factors apart from consumption of high levels of carbohydrates and inactivity. When the patient is diagnosed with hyperglycemia, they are advised about food intake and increasing physical

activity by entering an exercise program. There are drugs and nutritional supplements that will reduce the absorption of glucose in the intestines by inhibiting enzymes such as α amylase and α glucosidase, thereby, lowering postprandial glucose [37]. However, it has been recognized that there are many other factors such as pancreatic dysfunction, insulin resistance, imbalanced rate of glycogenolysis and gluconeogenesis and increased glucagon production result in increased production of endogenous glucose [38]. In addition, these patients may also have less insulin production with progressive β-cell dysfunction [39]. Therefore, diabetic patients may benefit more with plant products as these have multiple compounds that may affect multiple targets [40–43].

Traditional medicines have been popular in different parts of the world and some of them have been traced back to thousands of years - Chinese traditional medicine and Ayurveda. Many cultures around the world such as the American Indians, Mexican, Chinese, Indian subcontinent, various parts of Europe, Africans, Australians have incorporated locally available plants to treat diabetes [36]. Chinese traditional medicine describes bitter flavor and plants that release heat as the most important factors for treating T2DM [44]. Bitter flavor can consolidate the body, remove dampness and purge heat while cold property removes heat syndrome which is seen in T2DM patients during the initial and middle stages of the condition [44]. Ayurvedic treatment uses different approaches including plant medicines incorporated in the diet, exercise, medications, massage, sunlight, controlled breathing and detoxification [45].

There are hundreds of plants that are used in different traditional medicines to treat diabetes. We have listed a few of the most promising common plants that have anti-diabetic activity in animal models and human studies with minimum side effects in **Table 1**. A commonly used vegetable in Asia and Africa is bitter melon (*Momordica charantia*) (**Figure 2A**). This has multiple anti diabetic properties when consumed as fresh juice or eaten regularly. Side effects reported so far is diarrhea [44, 46–51]. Spices used in a wide variety of cuisines around the world like cinnamon (*Cinnamomum*) and some used in the Indian subcontinent such as fenugreek (*Trigonella foenum*) are also implicated in controlling hyperglycemia (**Figure 2B** and **C**). They are widely used in North Africa, Asia and South Europe to treat diabetes. Prolonged use of cinnamon may cause gastrointestinal problems, allergic reactions and liver disease in sensitive people due to the presence of coumarin. Little is known about the side-effects of fenugreek and is safe in amounts that are used for cooking, however, large doses may cause diarrhea, nausea and gastrointestinal issues [46, 52–64]. Green tea (*Camellia sinensis*) is now a common beverage around the world, although it has been used in East Asia for centuries. It has some benefits to diabetic patients and the side effects include insomnia, nausea and heartburn [65, 66] (**Figure 2D**). Basil (*Oscimum basilicum*) and gurmar (*Gymnema sylvestre*) are used in Ayurvedic medicine. Gurmar has many anti-diabetic properties compared to basil. Consumption of high levels of basil may cause liver damage, while Gurmar may cause hypoglycemia headache and nausea [46, 67–72]. Prickly pear (*Opuntia ficus-indica, Opuntia matudae*) is used widely in Central and South America as a vegetable. The health benefits of this fruit include anti-diabetic properties. Mild diarrhea with nausea when consumed in large quantities are the reported side-effects [73–76]. Chinese rhubarb (*Rheum palmatum*) has been studied for its anti-diabetic properties and has been in use in Chinese traditional medicine for a long time. Side effects reported are constipation, diarrhea, stomach pain and inflammation of the pancreas. [44, 77]. Overall, these plants have been part of cuisines for centuries. More long term randomized trials in different ethnic populations will be more informative. The side-effects should be considered, as understanding and keeping track of the side-effects will help in dose determination and sensitivity among patients. Another important factor to consider is the ethnic

Plant	Common name	Part of the plant used	Anti-diabetic properties	Area traditionally used as medicine	References
Momordica charantia	Bitter melon	Fruit	• ↓Glucose, HbA1C, fasting and PP glucose, PEPCK. • ↑Glucose uptake in cells, insulin signaling, GLUT4, PI3K, PPAR. • Antioxidative and anti inflammatory	Africa, China, India,	[26, 28–33]
Cinnamomum sp.	Cinnamon	Bark	• ↓Fasting glucose, HbA1C, PEPCK. • Mimics insulin in rodents, anti inflammatory, improves insulin sensitivity	China, India, Persia	[36–40, 42, 46]
Trigonella fienum-graecum	Fenugreek	Seeds, Leaves	• ↓Glucose, HbA1C, PP glucose. • ↑Insulin secretion • Renew pancreatic b cells	India, South Europe, Mediterranean	[34, 35, 41, 43–45]
Camellia sinensis	Tea- green	Leaves	• ↓HbA1C • Improves insulin sensitivity, glucose tolerance	Global	[47–48]
Gymnea sylvestre	Gurmar	Leaves	• ↓Glucose levels • ↑Insulin secretion, promotes islet cell regeneration, delays glucose absorption • binds to the receptors for sweet in the taste buds and inhibit sugar from binding	India	[28, 52–54]
Opuntia ficus-indica, O. matudkae	Nopal	Fruit	• ↓Intestinal absorption of glucose, PP glucose • Improves insulin sensitivity, anti-oxidative	Central and South America	[55–58]
Oscimum basilicum	Basil, Tulsi	Leaves	• ↓A glucosidase, a amylase, hyperglycemia • ↑Insulin stimulated glucose metabolism, GLUT4 translocation, liver glycogen content	South East Asia	[49–51]
Rheum palmatum	Chinese Rhubarb	Root	• ↓HbA1C, glucose, insulin resistance	Chinese	[26, 59]

PP = post prandial, HbA1C = Hemoglobin A1C, GLUT4 = Glucose transporter 4, PEPCK = Phosphoenol pyruvate carboxy kinase, PI3K = Phosphoinositide 3-kinase, PPAR = Peroxisome proliferator-activated receptor. ↓ = decrease, ↑ = increase.

Table 1.
List of some plants beneficial to diabetic patients.

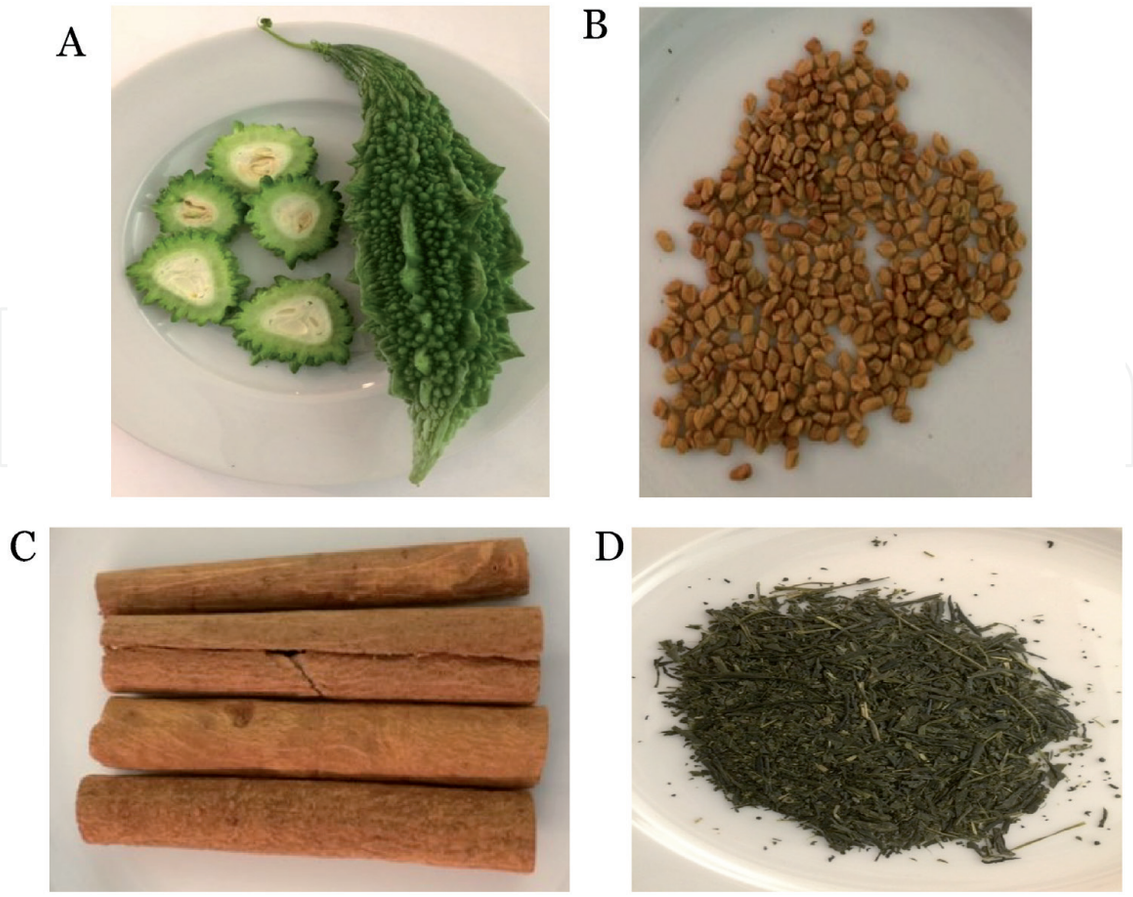

Figure 2.
Some herbal products beneficial to diabetic patients. (A) Bitter melon, (B) Fenogreekseeds and leaves, (C) cinnamon sticks, (D) driedgreentea.

background of the patient and their family history. This is very critical, as the response of patients to any therapy is dependent on these factors. This also calls for any medicine or diet prescription/counseling to be more individual specific.

Different parts of the plants are used – roots, stem, flowers, fruits and seeds. Each part of the plant may have different concentrations of phytochemicals which are the main players in the health benefits they show. Different compounds have been isolated from the potential medicinal plants and studied for their effects on the different pathways that are involved in the medical condition of interest.

3.1 Active ingredients/compounds

Some of the active ingredients have been characterized in either *in vitro* or *in vivo* studies including randomized control trials (RCT) for their anti-diabetic properties. Some of the common compounds studied are saponins, flavones, and polyphenols.

3.1.1 Saponins

Saponins increase liver glycogen synthesis, inhibit glycogen breakdown and promote insulin sensitivity in the peripheral tissues by increasing Glut 4 expression [78, 79]. Saponins also decrease body weight and inhibit enzymes that breakdown glucose [79, 80]. Found in legumes such as broad beans and lentils, bitter melon, asparagus, spinach and tea.

3.1.2 Flavonoids

Flavonoids are a group of compounds that are widely found in plant products and are implicated in several health benefits including T2DM. They inhibit enzymes that breakdown glucose and protect pancreatic β-cell damage, stimulate insulin secretion, promote glucose uptake in peripheral tissues, inhibit α amylase and α glucosidase and stimulate glycogenesis [43, 46, 80, 81]. Kaempferol inhibits hepatic inflammation, protects β cells by inhibiting apoptosis, lowers fasting glucose and improves insulin sensitivity [82–84]. They exhibit anti oxidative and anti-inflammatory properties as well [85]. Present in *Gingko biloba*, grapefruit broccoli, kale and tea. Anthocyanin also improves insulin sensitivity, decrease fasting sugar, in addition, it increases adiponectin and regulates glucose internalization via PPARγ, upregulates Glut4 and translocates Glut4 to membrane [86, 87]. It also increases AMPK in liver and muscle to increase glucose uptake and inhibit gluconeogenesis [88]. Found in tea, honey, nuts and many vegetables and fruits.

3.1.3 Polyphenols

Polyphenols are another group of compounds which include resveratrol, quercetin, epigallocathechin-3 gallate and triterpenoids have multiple targets in reducing hyperglycemia. Resveratrol reduces blood glucose, increases insulin secretion and modulates the enzymes of carbohydrate metabolism [89–91]. It also has anti-oxidative and by decreasing the production of proinflammatory cytokines it is anti-inflammatory as well [82]. Resveratrol is found in the skin of grapes, peanuts, coca, and berries like blueberries, bilberries and cranberries. Quercetin lowers body weight and decreases proinflammatory cytokines [92–94]. Onion has high quantities of quercetin but is also found in a variety of other vegetables and fruits including green leafy vegetable, apples, raspberries, red grapes and cherries. Epigallocathechin 3 gallate alters insulin secretion by increasing it and lowers glucose levels and body weight [95]. High levels are found in tea especially green tea. Triterpenoids can modulate insulin resistance [46, 49]. Found in bitter melon, olives, grapes, mango, apples, tomatoes and many other vegetables.

Alkaloids and polysaccharides present in plants may also control hyperglycemia [96].

4. Micronutrients

4.1 Minerals

Minerals like chromium magnesium and vanadium can influence hyperglycemia and are used in medications to treat T2DM. Chromium is poorly absorbed with age and T2DM patients have decreased levels of chromium [97]. Studies have shown that chromium deficiency causes reversible insulin resistance and when supplemented improves glycemic control [57]. Another mineral that most T2DM patients show low levels is magnesium [36]. Magnesium is a cofactor for many enzymes in glucose oxidation and it modulates glucose across cell membranes. Mg deficiency causes insulin resistance. It may increase insulin secretion and increase uptake of glucose in peripheral tissues [36]. Vanadium was used in certain insulin preparations and in animal models has shown increased uptake of glucose and its metabolism. It is also reported to increase insulin sensitivity. It may modulate glucose oxidation, glycogen synthesis and hepatic glucose output modulation [98].

4.2 Vitamins

Vitamins like vitamin C and E may also help T2DM patients. Vitamin C can improve glycemic control [99] while vitamin E, as an anti-oxidant, may influence protein glycation, insulin sensitivity and secretion [36].

5. Conclusions

Several diets have been studied to reduce the risk of developing diabetes and to control hyperglycemia. Almost all of them focus on decreasing body weight so they reduce body fat content as well. Many of the diets are beneficial in delaying the onset of diabetes and to diabetic patients. However, some of the diets require for the patients to be monitored constantly. Many plant products used in traditional medicine around the world have been scientifically studied to determine the efficacy, mechanism and side effects with focus of their effects on hyperglycemia. Diabetes being a complicated disease, T2DM patients may benefit more if multi targeted therapy is given. In addition to diet, another important factor that will help T2DM is the level of physical activity and exercise. Any diet with exercise is more beneficial than either one alone.

Mayo clinic recommends diet rich in fiber, vegetables, fruits and whole grain with low fat dairy products [100]. The American Diabetic Association and The American Heart Association recommend a balanced plate similar to that of USDA (**Figures 3** and **4**) with half plate of vegetables, a quarter plate of healthy carbohydrates such as brown rice, whole wheat couscous, whole grain pasta or plain sweet potato and some less than a quarter plate of protein [101, 102]. Fats are essential to the body as they are integral part of the cell membrane and hormones. They are required to digest any fat that is consumed. However, there has been a debate whether saturated fats are required for the body or not. The importance of having less than 10% saturated fat in the diet is now recognized although instead of saturated fatty acids, mono and poly unsaturated fatty acids are recommended. With respect to nutritional supplements there is no recommendation from American Diabetes Association. However, there is an increase in the number of patients seeking complementary and alternative medicine due to lower side effects and cost effectiveness. With a steady increase in scientific authentication of plant products for preventing and treating medical conditions nutritional supplements may become more popular. Interestingly, many of the plant products are consumed almost everyday in many cultures and these population also report diabetes. One reason maybe because they do not eat it everyday at the required dosage in addition to major change in lifestyle from an active on to a more sedentary one, as seen in any developed societies.

With many options for diets to choose from for patients, it is important to remember that as individuals differ among themselves, a individualized diet is important and equally important is adhering to the diet [103]. For diabetic patients to help control the progression of the disease, it is important to consider bio individual needs of each patients. Whether it is the choice of drugs, nutrition therapy or life style changes, it is important to have individually tailored treatment regimens for diabetic patients based on several factors including the ethnicity, life style, choice of foods etc. Other important factors to consider, in T2DM patients, are how much endogenous insulin is produced, and the level of insulin resistance to recommend diets that can target β-cell function and tissue-specific insulin sensitivity [104]. In T1DM patients it is critical to monitor the insulin that is administered and adjust

Figure 3.
USDA recommended 'my plate' showing recommended portions of each macronutrients: Carbohydrates (40–60%); proteins (10–35% for males; 13–15% for females), fats (20–35%). (fiber 25 g) https://www.fns.usda.gov/cnpp.

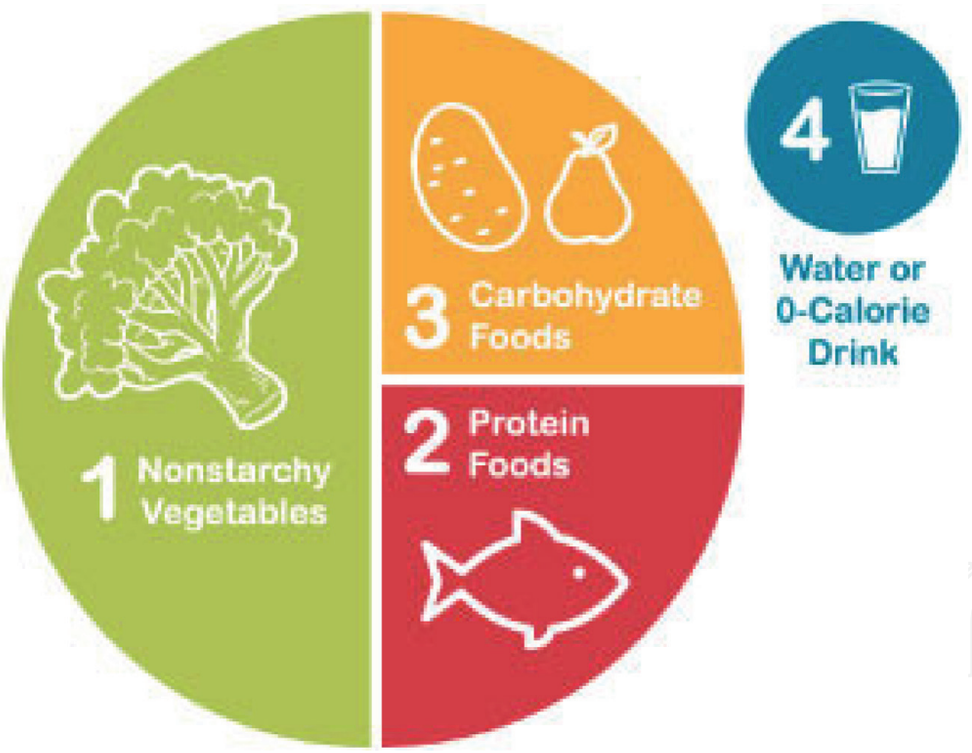

Figure 4.
ADA recommended plate model for balanced food intake. %0% vegetables, 25% protein and 25% carbohydrate is recommended with a glass of water or no calories drink. https://diabetes.org/nutrition.

the macronutrients to avoid hypoglycemic condition. Most of the time carbohydrate counting in the diet is recommended for T1DM patients.

Conflict of interest

The author declares no conflict of interest.

DOI: http://dx.doi.org/10.5772/intechopen.94645

Author details

Jameela Banu
Department of Health and Biomedical Sciences and Department of Biology, University of Texas Rio Grande Valley, Edinburg, Texas, USA

*Address all correspondence to: jameela.banu@utrgv.edu

References

[1] WHO. *Diabetes Overview*. 08/20/2020]; Available from : https://www.who.int/health-topics/diabetes/diabetes#tab=tab_1.

[2] Look, A.R.G., et al., *The Look AHEAD study: a description of the lifestyle intervention and the evidence supporting it.* Obesity (Silver Spring), 2006. **14**(5): p. 737-52.

[3] Steinberg, H., C. Jacovino, and A.E. Kitabchi, *Look inside Look AHEAD: why the glass is more than half-full.* Curr Diab Rep, 2014. **14**(7): p. 500.

[4] Uusitupa, M., et al., *The Finnish Diabetes Prevention Study.* Br J Nutr, 2000. **83 Suppl 1**: p. S137-42.

[5] Lindstrom, J., et al., *Sustained reduction in the incidence of type 2 diabetes by lifestyle intervention: follow-up of the Finnish Diabetes Prevention Study.* Lancet, 2006. **368**(9548): p. 1673-9.

[6] Lindstrom, J., et al., *Improved lifestyle and decreased diabetes risk over 13 years: long-term follow-up of the randomised Finnish Diabetes Prevention Study (DPS).* Diabetologia, 2013. **56**(2): p. 284-93.

[7] Diabetes Prevention Program Research, G., *The Diabetes Prevention Program (DPP): description of lifestyle intervention.* Diabetes Care, 2002. **25**(12): p. 2165-71.

[8] Pan, X.R., et al., *Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study.* Diabetes Care, 1997. **20**(4): p. 537-44.

[9] Bantle, J.P., et al., *Metabolic effects of dietary sucrose in type II diabetic subjects.* Diabetes Care, 1993. **16**(9): p. 1301-5.

[10] Sandouk, Z. and M.C. Lansang, *Diabetes with obesity--Is there an ideal diet?* Cleve Clin J Med, 2017. **84**(7 Suppl 1): p. S4-S14.

[11] Malik, V.S., et al., *Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis.* Diabetes Care, 2010. **33**(11): p. 2477-83.

[12] Samaha, F.F., et al., *A low-carbohydrate as compared with a low-fat diet in severe obesity.* N Engl J Med, 2003. **348**(21): p. 2074-81.

[13] Vetter, M.L., et al., *Long-term effects of low-carbohydrate versus low-fat diets in obese persons.* Ann Intern Med, 2010. **152**(5): p. 334-5.

[14] Association, A.D., *Introduction.* Diabetes Care, 2017. **40**(Suppl 1): p. S1-S2.

[15] Thomas, D., Elliott, E.J., *Low glycemic index or low glycemic load, diets for diabetes mellitus.* Cocharane Database Syst Rev, 2009. **1:CD006296**: p. 29.

[16] Braunstein, C.R., Meija, S.B., Stoiko, E., Noronha J.C., Choo, V., Ha, V., Augustin, L., Jenkins, D.J.A., Kendall, C.W.C., Sievenpiper, J.L. *Effect of low-glycemic index/load diets on body weight: A systemic Review and Meta-Analysis*. in *Experimental Biology*. 2016. San Diego: The FASEB Journal.

[17] Savage, D.B., K.F. Petersen, and G.I. Shulman, *Disordered lipid metabolism and the pathogenesis of insulin resistance.* Physiol Rev, 2007. **87**(2): p. 507-20.

[18] Evert, A.B., et al., *Nutrition therapy recommendations for the management of adults with diabetes.* Diabetes Care, 2014. **37 Suppl 1**: p. S120-43.

[19] Chang, J. and S.R. Kashyap, *The protein-sparing modified fast for obese patients with type 2 diabetes: what to expect.* Cleve Clin J Med, 2014. **81**(9): p. 557-65.

[20] Ajala, O., P. English, and J. Pinkney, *Systematic review and meta-analysis*

of different dietary approaches to the management of type 2 diabetes. Am J Clin Nutr, 2013. **97**(3): p. 505-16.

[21] Staff, M.C. *Paleo diet: What is it and why is it so popular?* 10/08/2020]; Available from: https://www.mayoclinic.org/healthy-lifestyle/nutrition-and-healthy-eating/in-depth/paleo-diet/art-20111182.

[22] Tarantino, G., V. Citro, and C. Finelli, *Hype or Reality: Should Patients with Metabolic Syndrome-related NAFLD be on the Hunter-Gatherer (Paleo) Diet to Decrease Morbidity?* J Gastrointestin Liver Dis, 2015. **24**(3): p. 359-68.

[23] Jonsson, T., et al., *Beneficial effects of a Paleolithic diet on cardiovascular risk factors in type 2 diabetes: a randomized cross-over pilot study.* Cardiovasc Diabetol, 2009. **8**: p. 35.

[24] Jew, S., S.S. AbuMweis, and P.J. Jones, *Evolution of the human diet: linking our ancestral diet to modern functional foods as a means of chronic disease prevention.* J Med Food, 2009. **12**(5): p. 925-34.

[25] Freeman, J.M., E.H. Kossoff, and A.L. Hartman, *The ketogenic diet: one decade later.* Pediatrics, 2007. **119**(3): p. 535-43.

[26] Hamdy, O., et al., *Fat Versus Carbohydrate-Based Energy-Restricted Diets for Weight Loss in Patients With Type 2 Diabetes.* Curr Diab Rep, 2018. **18**(12): p. 128.

[27] Bolla, A.M., et al., *Low-Carb and Ketogenic Diets in Type 1 and Type 2 Diabetes.* Nutrients, 2019. **11**(5).

[28] Nielsen, J.V., et al., *Low carbohydrate diet in type 1 diabetes, long-term improvement and adherence: A clinical audit.* Diabetol Metab Syndr, 2012. **4**(1): p. 23.

[29] Fabricatore, A.N., Herron, L.A., Wadden, T.A., *Reduction in glycemic variability and hyperglycemia with a low-glycemic index portion controlled diet in persons with type 2 diabetes.*, in *American Diabetes Association*. 2012: Philadelphia.

[30] Foster, G.D., et al., *The effects of a commercially available weight loss program among obese patients with type 2 diabetes: a randomized study.* Postgrad Med, 2009. **121**(5): p. 113-8.

[31] Foster, G.D., Wadden, T.A., LaGrotte, C.A., Hesson, L.A., Komaroff, E., VanderVeur, S.S., Homko, C.J., Maschak-Carry, B.J., Reyner, N., Diewald, L.K., Kiotz, A.L., Wojtanowski, A., Herring, S., Tioxon, D.A., Vetter, M., Sanders, T., *The effects of a portion controlled meal plan versus a diabetes self-management program on weight and glycemic control among obese patients with type 2 diabates.*, in *American Scientific Meeting of the Obesity Society*. 2011: Orlando, FL.

[32] Rosenthal, J., *Integrative Nutrition*. 2014, New York: Institute for Integrative Nutrition.

[33] Marian M.J. & Mullin, G.E., *Integrative Nutrition Therapy*. 2016, Boca Raton, FL: CRC Press.

[34] Organization, W.H., *Traditional medicine - growing needs and potential, WHO policy persespective on medicine.* 2002. **2**: p. 1-6.

[35] Rizvi, S.I. and N. Mishra, *Traditional Indian medicines used for the management of diabetes mellitus.* J Diabetes Res, 2013. **2013**: p. 712092.

[36] Yeh, G.Y., et al., *Systematic review of herbs and dietary supplements for glycemic control in diabetes.* Diabetes Care, 2003. **26**(4): p. 1277-94.

[37] Senthil, S.L., Raghu, C., Arjun, H., Anantharaman, P., *In vitro and in silico inhibition properties of fucoidan against α-amylase and α-D-glucosidase*

with relevance to type 2 diabetes mellitus. Carbohydrate Polymers, 2019. **209**: p. 350-355.

[38] Van Poelje, P.D., Dang, Q., Erion, M.D., *Fructose-1, 6 bisphosphatase as a therapeutic target for type 2 diabetes.* Drug Discovery Today Therapeutic Strategies, 2007. **4**: p. 103-109.

[39] Fryirs, M., P.J. Barter, and K.A. Rye, *Cholesterol metabolism and pancreatic beta-cell function.* Curr Opin Lipidol, 2009. **20**(3): p. 159-64.

[40] Csermely, P., V. Agoston, and S. Pongor, *The efficiency of multi-target drugs: the network approach might help drug design.* Trends Pharmacol Sci, 2005. **26**(4): p. 178-82.

[41] Peters, J.U., *Polypharmacology - foe or friend?* J Med Chem, 2013. **56**(22): p. 8955-71.

[42] Reddy, A.S. and S. Zhang, *Polypharmacology: drug discovery for the future.* Expert Rev Clin Pharmacol, 2013. **6**(1): p. 41-7.

[43] Pereira, A.S.P., et al., *Evaluation of the Anti-Diabetic Activity of Some Common Herbs and Spices: Providing New Insights with Inverse Virtual Screening.* Molecules, 2019. **24**(22).

[44] Chen, H., et al., *Application of Herbal Medicines with Bitter Flavor and Cold Property on Treating Diabetes Mellitus.* Evid Based Complement Alternat Med, 2015. **2015**: p. 529491.

[45] Shekelle, P.G., Hardy, M., Morton, S.C., Coulter, I., Venuturnpalli, S., Favreau, J., Hilton, L.K. , *Are Ayurvedic herbs for diabetes effective?* The Journal of Family Practice, 2005. **54**: p. 876-886.

[46] Ota, A., Ulrih, N.P., *An overview of herbal products and secondary metabolites used for managemnent of type two diabete.* Frontiers in Pharmacology, 2017. **8**: p. 1-14.

[47] Sun, F.Q., Zhang, G., Huang, B., Bai, J., Yu, X. , *Clinical observation of using bitter melon to treat DM.* Lisoning J of PRactical Diabetaology, 2000. **8**: p. 34-35.

[48] Kumar, R., et al., *Fruit extracts of Momordica charantia potentiate glucose uptake and up-regulate Glut-4, PPAR gamma and PI3K.* J Ethnopharmacol, 2009. **126**(3): p. 533-7.

[49] Giovannini, P., M.J. Howes, and S.E. Edwards, *Medicinal plants used in the traditional management of diabetes and its sequelae in Central America: A review.* J Ethnopharmacol, 2016. **184**: p. 58-71.

[50] Leatherdale, B.A., et al., *Improvement in glucose tolerance due to Momordica charantia (karela).* Br Med J (Clin Res Ed), 1981. **282**(6279): p. 1823-4.

[51] Omokhua-Uyi, A.G. and J. Van Staden, *Phytomedicinal relevance of South African Cucurbitaceae species and their safety assessment: A review.* J Ethnopharmacol, 2020. **259**: p. 112967.

[52] Al-Habori, M., Al-Aghbari, AM. Al-Mamary, E., *Antidiabetic and hypocholestrolaemic effects of fenugreek.* Phytother Res, 1998. **12**: p. 233-242.

[53] Valette, G., et al., *Hypocholesterolaemic effect of fenugreek seeds in dogs.* Atherosclerosis, 1984. **50**(1): p. 105-11.

[54] Sheng, X., et al., *Improved Insulin Resistance and Lipid Metabolism by Cinnamon Extract through Activation of Peroxisome Proliferator-Activated Receptors.* PPAR Res, 2008. **2008**: p. 581348.

[55] Khan, A., et al., *Cinnamon improves glucose and lipids of people with type 2 diabetes.* Diabetes Care, 2003. **26**(12): p. 3215-8.

[56] Crawford, P., *Effectiveness of cinnamon for lowering hemoglobin A1C in patients with type 2 diabetes: a randomized, controlled trial.* J Am Board Fam Med, 2009. **22**(5): p. 507-12.

[57] Nahas, R. and M. Moher, *Complementary and alternative medicine for the treatment of type 2 diabetes.* Can Fam Physician, 2009. **55**(6): p. 591-6.

[58] Mang, B., et al., *Effects of a cinnamon extract on plasma glucose, HbA, and serum lipids in diabetes mellitus type 2.* Eur J Clin Invest, 2006. **36**(5): p. 340-4.

[59] Madar, Z., et al., *Glucose-lowering effect of fenugreek in non-insulin dependent diabetics.* Eur J Clin Nutr, 1988. **42**(1): p. 51-4.

[60] Akilen, R., et al., *Glycated haemoglobin and blood pressure-lowering effect of cinnamon in multi-ethnic Type 2 diabetic patients in the UK: a randomized, placebo-controlled, double-blind clinical trial.* Diabet Med, 2010. **27**(10): p. 1159-67.

[61] Gupta, A., R. Gupta, and B. Lal, *Effect of Trigonella foenum-graecum (fenugreek) seeds on glycaemic control and insulin resistance in type 2 diabetes mellitus: a double blind placebo controlled study.* J Assoc Physicians India, 2001. **49**: p. 1057-61.

[62] Kochhar, A. and M. Nagi, *Effect of supplementation of traditional medicinal plants on blood glucose in non-insulin-dependent diabetics: a pilot study.* J Med Food, 2005. **8**(4): p. 545-9.

[63] NCCIH. *Fenugreek*. 08/22/2020]; Available from: https://www.nccih.nih.gov/health/fenugreek.

[64] NCCIH. *Cinnamon*. 08/22/2020]; Available from: https://www.nccih.nih.gov/health/cinnamon.

[65] Fukino, Y., et al., *Randomized controlled trial for an effect of green tea-extract powder supplementation on glucose abnormalities.* Eur J Clin Nutr, 2008. **62**(8): p. 953-60.

[66] Venables, M.C., et al., *Green tea extract ingestion, fat oxidation, and glucose tolerance in healthy humans.* Am J Clin Nutr, 2008. **87**(3): p. 778-84.

[67] Broadhurst, C.L., M.M. Polansky, and R.A. Anderson, *Insulin-like biological activity of culinary and medicinal plant aqueous extracts in vitro.* J Agric Food Chem, 2000. **48**(3): p. 849-52.

[68] El-Beshbishy, H., Bahashwan, S., *Hypoglycemic effect of basil (Ocimum basilicum) aqueous extract ismediated through inhibition of α-glucosidase and a-amylase activities: An invitro study.* Toxicol Ind Health, 2012. **28**: p. 42-50.

[69] Ezeani, C., et al., *Ocimum basilicum extract exhibits antidiabetic effects via inhibition of hepatic glucose mobilization and carbohydrate metabolizing enzymes.* J Intercult Ethnopharmacol, 2017. **6**(1): p. 22-28.

[70] Baskaran, K., et al., *Antidiabetic effect of a leaf extract from Gymnema sylvestre in non-insulin-dependent diabetes mellitus patients.* J Ethnopharmacol, 1990. **30**(3): p. 295-300.

[71] Li, Y., et al., *Effect of-Gymnema Sylvestre, Citrullus colocynthis and Artemisia absinthium on Blood Glucose and Lipid Profile in Diabetic Human.* Acta Pol Pharm, 2015. **72**(5): p. 981-5.

[72] Kamble, B., et al., *Effects of Gymnema sylvestre extract on the pharmacokinetics and pharmacodynamics of glimepiride in streptozotocin induced diabetic rats.* Chem Biol Interact, 2016. **245**: p. 30-8.

[73] McKennon, S.A., *Non-Pharmaceutical Intervention Options For Type 2 Diabetes: Diets And Dietary*

Supplements (Botanicals, Antioxidants, and Minerals), in *Endotext*, K.R. Feingold, et al., Editors. 2000: South Dartmouth (MA).

[74] Frati, A.C., et al., *Acute hypoglycemic effect of Opuntia streptacantha Lemaire in NIDDM.* Diabetes Care, 1990. **13**(4): p. 455-6.

[75] Lopez-Romero, P., et al., *The effect of nopal (Opuntia ficus indica) on postprandial blood glucose, incretins, and antioxidant activity in Mexican patients with type 2 diabetes after consumption of two different composition breakfasts.* J Acad Nutr Diet, 2014. **114**(11): p. 1811-8.

[76] Zhao, L.Y., et al., *Antidiabetic effect of a newly identified component of Opuntia dillenii polysaccharides.* Phytomedicine, 2011. **18**(8-9): p. 661-8.

[77] Wang, S.F., *The experimental study of the effect of alcohol extract from Rhenum palmatum L on diabetes type 2 rats with insulin resistance.* Modern J of Integrated Traditional Med and Western Med, 2007. **16**: p. 1606-1719.

[78] Ma, C.-Y., Yu, H.-Y., Wang, H.-J, Geng, L.-J., Guan, H.-Y, *Hypoglycemic mechanism of total saponins of Momordica charantia in typer 2 diabetes mellitus rats.* Tianjin Medical J, 2014. **42**: p. 321-324.

[79] Ma, C.Y., Yu, H.Y., Wang, H.J., Guan, H.Q., *Effects of total saponins of Momordica charantia on plasma lipids and adipocyte factors in type 2 diabetes rats.* Pharmacology and Clinics of Chinese Materia Medica, 2013. **29**: p. 56-59.

[80] Chen, L.H., Pan, Z.H., Cao, Y.L. Ma, Q.Y. , *A screen of α-glucosidase inhibitors from rhizoma anemarrhenae.* Food & Machinery, 2013. **29**: p. 147.

[81] Chen, J., et al., *Natural flavonoids as potential herbal medication for the treatment of diabetes mellitus and its complications.* Nat Prod Commun, 2015. **10**(1): p. 187-200.

[82] Luo, C., et al., *Kaempferol alleviates insulin resistance via hepatic IKK/NF-kappaB signal in type 2 diabetic rats.* Int Immunopharmacol, 2015. **28**(1): p. 744-50.

[83] Zhang, Y. and D. Liu, *Flavonol kaempferol improves chronic hyperglycemia-impaired pancreatic beta-cell viability and insulin secretory function.* Eur J Pharmacol, 2011. **670**(1): p. 325-32.

[84] Vinayagam, R. and B. Xu, *Antidiabetic properties of dietary flavonoids: a cellular mechanism review.* Nutr Metab (Lond), 2015. **12**: p. 60.

[85] Calderon-Montano, J.M., et al., *A review on the dietary flavonoid kaempferol.* Mini Rev Med Chem, 2011. **11**(4): p. 298-344.

[86] Stull, A.J., et al., *Bioactives in blueberries improve insulin sensitivity in obese, insulin-resistant men and women.* J Nutr, 2010. **140**(10): p. 1764-8.

[87] Scazzocchio, B., et al., *Cyanidin-3-O-beta-glucoside and protocatechuic acid exert insulin-like effects by upregulating PPARgamma activity in human omental adipocytes.* Diabetes, 2011. **60**(9): p. 2234-44.

[88] Kurimoto, Y., et al., *Black soybean seed coat extract ameliorates hyperglycemia and insulin sensitivity via the activation of AMP-activated protein kinase in diabetic mice.* J Agric Food Chem, 2013. **61**(23): p. 5558-64.

[89] Palsamy, P. and S. Subramanian, *Resveratrol, a natural phytoalexin, normalizes hyperglycemia in streptozotocin-nicotinamide induced experimental diabetic rats.* Biomed Pharmacother, 2008. **62**(9): p. 598-605.

[90] Palsamy, P. and S. Subramanian, *Ameliorative potential of resveratrol on proinflammatory cytokines, hyperglycemia mediated oxidative stress, and pancreatic beta-cell dysfunction in streptozotocin-nicotinamide-induced diabetic rats.* J Cell Physiol, 2010. **224**(2): p. 423-32.

[91] Palsamy, P., S. Sivakumar, and S. Subramanian, *Resveratrol attenuates hyperglycemia-mediated oxidative stress, proinflammatory cytokines and protects hepatocytes ultrastructure in streptozotocin-nicotinamide-induced experimental diabetic rats.* Chem Biol Interact, 2010. **186**(2): p. 200-10.

[92] Cherniack, E.P., *Polyphenols: planting the seeds of treatment for the metabolic syndrome.* Nutrition, 2011. **27**(6): p. 617-23.

[93] Rivera, L., et al., *Quercetin ameliorates metabolic syndrome and improves the inflammatory status in obese Zucker rats.* Obesity (Silver Spring), 2008. **16**(9): p. 2081-7.

[94] Yin, J., H. Zhang, and J. Ye, *Traditional chinese medicine in treatment of metabolic syndrome.* Endocr Metab Immune Disord Drug Targets, 2008. **8**(2): p. 99-111.

[95] Li, C., et al., *Green tea polyphenols modulate insulin secretion by inhibiting glutamate dehydrogenase.* J Biol Chem, 2006. **281**(15): p. 10214-21.

[96] Chen, Z.H., *Advances on hypoglycemic functions of bitter gourd components.* J Food Industry, 2014. **35**: p. 250-252.

[97] *A scientific review: the role of chromium in insulin resistance.* Diabetes Educ, 2004. **Suppl**: p. 2-14.

[98] O'Connell, B., *Select vitamins and minerals in the management of diabetes.* Diabetes Spectrum, 2001. **14**: p. 133-148.

[99] Eriksson, J. and A. Kohvakka, *Magnesium and ascorbic acid supplementation in diabetes mellitus.* Ann Nutr Metab, 1995. **39**(4): p. 217-23.

[100] Staff, M.C. *Diaetes diet: Create your healthy-eating plan*. [cited 2020 08/30/2020]; Available from: https://www.mayoclinic.org/diseases-conditions/diabetes/in-depth/diabetes-diet/art-20044295.

[101] Association, A.H. *The Diabetic Diet*. [cited 2020 9/27/2020]; Available from: https://www.heart.org/en/health-topics/diabtes/prevention-treatment-of-diabtes/the diabetic diet.

[102] Association, A.D. *Nutrition Eating does not have to be boring*. 8/30/2020]; Available from: https://diabetes.org/nutrition.

[103] Khazrai, Y.M., G. Defeudis, and P. Pozzilli, *Effect of diet on type 2 diabetes mellitus: a review.* Diabetes Metab Res Rev, 2014. **30 Suppl 1**: p. 24-33.

[104] Guess, N.D., *Dietary Interventions for the Prevention of Type 2 Diabetes in High-Risk Groups: Current State of Evidence and Future Research Needs.* Nutrients, 2018. **10**(9).