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Potential properties of legumes as important functional foods for management of type 2 diabetes: A short review

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Abstract: The concept of functional foods in health promotion and disease management has been developed during the past two decades. Beyond the basic nutritional functions, functional foods have several potential biological properties and have hence been given much attention. Leguminous seeds (peas, beans, lentils, peanuts), rich sources of bioactive proteins and peptides, functional fiber, indigestible carbohydrates and phytochemicals, have been recently introduced them as unique functional foods. Studies showed that higher consumption of legumes could attenuate postprandial glycemia and insulinemia, increase insulin sensitivity, regulate lipid and lipoprotein metabolism, and diminish oxidative stress. The potential efficacies of leguminous seeds and their bioactive components have made them as excellent choice for supplementary treatment in type 2 diabetes.

Keywords: Type 2 Diabetes, Functional Foods, Legumes, Insulin Resistance, Glucose Homeostasis, Dyslipidemia

1. Introduction

Type 2 diabetes is a multi-clustering metabolic disorders accompanied with abnormal glucose homeostasis, developing insulin resistance, impaired lipid and lipoprotein metabolism as well as increased oxidative stress and sub-clinical inflammation [1-4], which may lead to long term pathogenic conditions such as micro- and macro-vascular complications including neuropathy, retinopathy, nephropathy, disability and death in diabetic patients [5,6]. Traditionally, some medicinal plants and herbs were used as effective treatment for diabetic patients; recently use of functional foods and their nutraceutical components has been considered as supplementary treatment in the management of diabetes and prevention of its long-term complications (7,8). Whole grains, legumes, phytochemical rich fruits and vegetables, as well as prebiotics and probiotics rich foods are the main components of a functional food diet (8). In this review we have highlighted biological properties as well as potential efficacies of legumes as important functional foods and main components of medical nutrition therapy (MNT) in management of type 2 diabetes and prevention of its long-term complication.

2. Bioactive Components and Nutraceuticals of Legumes

In the past, legumes were consumed as the main staple foods in traditional dietary patterns; they are valuable sources of essential micronutrients and some important nutraceuticals. Legumes are rich in high-biological value proteins, bioactive peptides and essential amino acids (9).

Non-digestible carbohydrates and slowly digestible starch including dietary fiber, resistance starches and oligosaccharides (α-galactosides) are the most of carbohydrates of legumes (10). Dietary fiber content of leguminous seeds was reported ranging from 8-27.5% (soluble fiber ranges 3.3-18.3%) of dry weight (11).

Other bioactive compounds such as functional fatty acids (linoleic acid, α-linolenic acid), isoflavones (daidzein, genistein, glycitein), phenolic acids, saponins, and phytic acid; some polyphenols including pelargonidin, cyanidin, delphinidin, and malvidin are also found in legumes (9).

3. Potential Properties of Legumes in Glycemic Control

Legumes are considered a component of a healthy diet and there is much evidence showing that regular consumption of legumes has protective effects against obesity, type 2 diabetes, and cardiovascular diseases (12,13).

Various aspects of nutritional properties of legumes have been highlighted in the literatures; digestibility of main nutrients, colonic fermentation of oligosaccharides and resistance starch, as well as postprandial glycemic and insulinemic responses and effects of legumes on lipid and lipoprotein metabolism are the main of them (9,11).

Studies showed that a substantial replacement of rapidly digested dietary carbohydrate with legumes could improve glycemic control. A three-month dietary intervention in type 2 diabetic patients showed that the low-glycemic index legume diet compared to the high wheat fiber diet had greater effect on reduction of HbA1c levels (-0.2%, 95% CI= -0.3% to -0.1%, $P<0.001$). A significant grater reduction in coronary heart disease risk score was also observed in the low-GI legume diet compared to the high wheat fiber diet (14).

The α-amylase inhibitory peptides are one of the bioactive compounds in legumes and beans that reduce digestion and absorption of dietary carbohydrates, and modulate postprandial glycemic response; other bioactive peptides of grain legumes including the 7S globulin α′ chain and conglutin γ have unique properties to regulate lipid metabolism and normalize lipid and lipoprotein levels (15). It is suggested insoluble fiber in legumes could attenuate the rate of digestion and absorption of carbohydrates, and subsequently reduce postprandial glycemia; intestinal production of short chain fatty acids through fermentation of resistance starch and indigestible carbohydrates is another potential mechanism could be explained anti-hyperglycemic effect of legumes (16).

4. Most Common Consumed Legumes and their Beneficial Effects

Lentil (*Lens culinaris*) is the most common consumed leguminous seed. One-hundred grams of lentil contains 116.7 kcal energy, 9.04 g protein, 20.1 g carbohydrates, 0.37 g fat and 4.94 g dietary fibers. Lentil is rich sources of dietary fiber, slowly digestible starch and resistant starch, oligosaccharides, phytosterols, tannins, saponins, β-glucan, functional antioxidant ingredients, a wide range of phenolic acids including gallic acid, proanthcyanidins, prodelphinidin, procyanidins, catechins, epicatechin, kampferol, quercetin, cinapic acid and apigenin (17,18). Several bioactive proteins and glycoproteins are also found in lentil such as lectins, defensins, and protease inhibitors (19). High levels of magnesium, calcium, phosphorous, selenium, potassium, zinc and manganese are also present in lentil; total phenolic compounds of lentil has been estimated as 26 mg gallic acid equivalent per 100 g of fresh weight (19). Greater amount of amylase compared to amylopectin is found in lentil and moreover, resistance starch in cooked lentil is about 48% of total starch; so this functional food should be considered as an appropriate alternative source of carbohydrate in diet planning of type 2 diabetic patients.

Limited studies have been conducted to evaluate effect of lentil on glycemic control in type 2 diabetic patients. In a randomized cross-over clinical trial, 6 weeks following of a diet containing 50 g/d cooked lentil, significantly decreased fasting blood glucose (20); in this study lentil consumption led to a significant decrease in total cholesterol (20). Polyphones of lentil could prevent angiotensin II-induced hypertension, and pathological changes including vascular remodeling and vascular fibrosis (21).

Dry beans such as pinto and kidney beans, split peas, chickpeas, lentils, and soybeans, are also other important legume grains in the human diet; dry beans have high content of resistance starch, dietary fiber, oligosaccharides, ω_3 fatty acid, antioxidants, and phytochemicals including phytates, saponins and phenolic compounds. The hypoglycemic effect of beans (via inhibition of α-amylase and β-glucosidase activity) has been reported as being similar to those of anti-diabetic drugs (22-24). Studies reported that usual consumption of dry beans in diet had protective effect against developing cardiovascular disease and diabetes. Including beans (pinto, dark red kidney, black beans) in diet planning for type 2 diabetic patients effectively helps weight management, attenuates postprandial glycemic response, and improves dyslipidemia (25,26).

Soybean, a rich source of unique phytoesterogens (genistein, daidzein, glycitein), is another important functional food which has been considered in diabetes; the isoflavones and bioactive peptides of soybean have favorable effects on glycemic control and insulin sensitivity, dyslipidemia, and kidney function (27-30). It seems that the anti-diabetic effects of soybean mainly occur through interaction of estrogen receptors (ERs). Soy isoflavones selectively bind to both α and β estrogen receptors; ERα is considered as key modulator of glucose and lipid metabolism, and regulate insulin biosynthesis and secretion as well as pancreatic β-cell survival (30, 31).

Soy protein could induce insulin sensitivity and improve lipid homeostasis via activation of peroxisome proliferator-activated receptor (PPARs) and liver X receptors (LXR), and inhibition of the sterol regulatory element binding protein-1c (31). Regular consumption of soy products could help diabetic patients in the management of dyslipidemia (32). Soy protein and isoflavones decrease production of atherogenic apolipoproteins such as apo B, increase biosynthesis of HDL-C, induce LDL-C receptors, increase biosynthesis and excretion of bile acids, decrease gastrointestinal absorption of steroids, induce favorable changes in hormonal status, including the insulin to glucagon ratio, and thyroid hormones which lead to improvement of dyslipidemia (33,34).

Recently two bioactive peptides, identified in glycinin (a main soy protein), have unique hypolipidemic properties. These peptides inhibit 3-hydroxy-3methyl glutaryl CoA reductase, key enzyme involved in cholesterol biosynthesis. β-canglycinin, another main soy bioactive protein with anti-atherogenic properties via regulation of lipogenesis, decease liver lipogenic enzyme activity, inhibits fatty acid biosynthesis in liver, and facilitates fatty acid β-oxidation; other biological activities of soy peptides include antioxidant, anti-inflammatory, and hypotensive effect (35).

Another feature of soybean and soy products as well as other legumes which may highlight them as main part of a functional foods-based diet, is their established effectiveness in weigh management; since the overweight and obesity are the common problems in diabetic patients and main contributors in development of insulin resistance, benefit from anti-obesity properties of legumes is considered another key approach in these patients. Thermogenic effects, induction of satiety through some important appetite regulatory gut peptides, mediation in gene expression and secretion of key adipocytokines such as leptin and adiponectin, as well as inhibitory effects on proliferation and differentiation of adipocytes are some of the mechanisms that could explain the role of legumes on weight management (36-39).

In conclusion, with respect to low glycemic index, high fiber and phytochemical content of legumes, and also considering the potential properties of legumes and its by products, it is recommended that regular consumption of these functional foods is considered as an effective strategy for management of various aspects of type 2 diabetes.

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