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Review

Spices in the management of diabetes mellitus

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ABSTRACT

Diabetes mellitus (DM) remains a major health care problem worldwide both in developing and developed countries. Many factors, including age, obesity, sex, and diet, are involved in the etiology of DM. Nowadays, drug and dietetic therapies are the two major approaches used for prevention and control of DM. Compared to drug therapy, a resurgence of interest in using diet to manage and treat DM has emerged in recent years. Conventional dietary methods to treat DM include the use of culinary herbs and/or spices. Spices have long been known for their antioxidant, anti-inflammatory, and anti-diabetic properties. This review explores the anti-diabetic properties of commonly used spices, such as cinnamon, ginger, turmeric, and cumin, and the use of these spices for prevention and management of diabetes and associated complications.

Contents

Abbreviations: AMPK, 5′ adenosine monophosphate-activated protein kinase; AGE, advanced glycation end-product; BP, blood pressure; CE, cinnamon extracts; CP, cinnamon polyphenols; DM, diabetes mellitus; eNOS, endothelial nitric oxide synthase; FBG, fasting blood glucose; FDA, Food and Drug Administration; FFA, free fatty acid; G6Pase, glucose-6-phosphatase; GLP-1, glucagon-like peptide 1; GLUT4, glucose transporter type 4; GPX, glutathione peroxidase; GRAS, Generally Recognized As Safe; HDL, high-density lipoprotein; HbA1c, hemoglobinA1c; hsCRP, high-sensitivity C-reactive protein; IPF, insulin potentiating factor; IRS-1, insulin receptor substrate 1; IDDM, insulin-dependent diabetes mellitus; JNK, c-Jun N-terminal kinase; LDL, low-density lipoprotein; NF-κB, nuclear factor-kappaB; NIDDM, non-insulin-dependent diabetes mellitus; PEPCK, phosphoenolpyruvate carboxykinase; PKC, protein kinase C; PPAR-γ, peroxisome proliferator-activated receptor gamma; PTP-1, protein tyrosine phosphatase; ROS, reactive oxygen species; SBP, systolic blood pressure; SGLT1, sodium-glucose linked transporter 1; SOD, superoxide dismutase; STZ, streptozotocin; T1D, type 1 diabetes; T2D, type 2 diabetes; VARC, volume regulated anion channel.

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1. Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder of the endocrine system that continues to be a major health care problem worldwide. The prevalence of DM is expected to rise from the current 382 million individuals to 471 million by 2035 (IDF Diabetes Atlas. Sixth edition., 2013). Diabetes is clinically characterized by hyperglycemia (high blood glucose concentration) and the disturbance of carbohydrates, protein, and fat metabolism due to chronic and/or relative insufficiency in insulin secretion and action (Bastaki, 2005). Untreated, diabetes can cause many complications and affect the eyes, nerves, kidneys, and blood vessels, and even lead to premature death (Forbes & Cooper, 2013). It is believed that hyperglycemia is also one of the most important factors in the development of diabetes and associated complications. The adverse effects of hyperglycemia may be derived from four metabolic pathways, including: activation of protein kinase C (PKC) isoforms (Geraldes & King, 2010), increased hexosamine pathway flux (James et al., 2002), increased advanced glycation end-product (AGE) formation (Peppa, Uribarri, & Vlassara, 2004), and increased aldose-reductase pathway flux (Rolo & Palmeira, 2006).

Drugs with anti-diabetic properties, coupled with insulin treatment, appropriate diet, and exercise, remain the main approach in the treatment of diabetes. However, existing pharmaceutical treatments have toxic side effects and, sometimes, prolonged use leads to diminished response (Hollander, 2007). In contrast, phenolic compounds in commonly consumed plant-based foods have attracted considerable attentions recently for being endowed with compounds protective against diabetes (Perera & Handuwalage, 2015). Compared to synthetic drugs, the food components of plant origin are natural, economical, and more appealing to consume. Spices, in addition to fruits and vegetables, are the main dietary sources of phenolic compounds. The polyphenols (one group of the phenolic compounds) in 80 spices have been proven to exhibit anti-glycation properties, which contribute to the prevention and management of DM (Elosta, Ghous, & Ahmed, 2012). The spice polyphenols may influence glucose metabolism via several mechanisms, such as glucose absorption in the intestine, stimulation of insulin secretion from pancreatic β-cells, modulation of glucose release from the liver, activation of insulin receptors and glucose uptake in the insulin-sensitive tissues, and modulation of hepatic glucose output (Fig. 1). Therefore, the seasoning of foods with spices has been suggested not only to increase the antioxidant content of meals, but also to have an anti-diabetic effect.

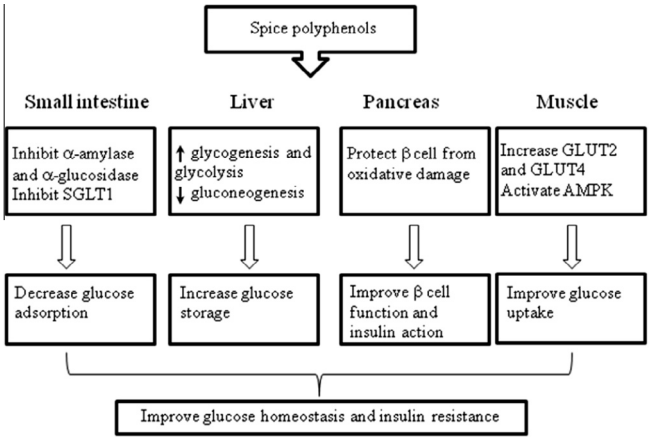

Fig. 1. The beneficial effects of spice polyphenols on glucose homeostasis and insulin resistance.

To date, various intact spices and spice extracts (as shown in Tables 1a and 1b, respectively) have been used successfully to manage type 2 diabetes (T2D), which makes up 90% of cases of DM. Despite the beneficial effects of spices in reducing fasting and postprandial glucose levels, interpretation of the actions of bioactive compounds in spices still remains complicated. This is due to the fact that each spice contains a wide range of phenolic compounds and a synergistic effect may exist. Moreover, the daily intake of individual spices differs between regions and the bioavailability of the phenolic compounds in spices is affected by various chemical and biological factors. Therefore, a better understanding of the anti-diabetic potential of the bioactive compounds in common spices should help in the prevention of diabetes, and associated complications and metabolic abnormalities. Herein, we evaluate the beneficial effects of commonly consumed spices, especially cinnamon, ginger, turmeric, cumin, coriander, aniseed, fenugreek, garlic and onion, cloves, mustard, black pepper and curry leaves for the management of DM. The bioactive compounds and their bioavailability are also discussed.

2. Phenolic compounds

The positive effects of spices on health have been partly attributed to their complex mixture of phenolic compounds (Bower, Marquez, & De Mejia, 2015). Phenolics refer to a large number of compounds having one or more aromatic ring with at least one hydroxyl groups attached. They range from small and single aromatic-ringed compounds to large 110 polyphenols classified as flavonoids (Pereira, Valentao, Pereira, & Andrade, 2009). Table 2a shows some examples of phenolic compounds, including polyphenols, terpenes, vanilloids, and organosulfur compounds found in commonly used spices. Among them, polyphenols are classified in flavonoids (including flavanols, flavanones, flavones, and flavonols) and non-flavonoids (such as phenolic acids). Flavonoids have been reported to have antioxidant, anti-cancer, anti-allergic, anti-inflammatory, and gastro-protective properties (Cook & Sammans, 1996). Emerging research has also suggested that terpenes, vanilloids, and organosulfur compounds possess antioxidant properties and protect against chronic diseases like DM.

3. Diabetes mellitus

DM occurs when the body is unable to produce enough insulin or use insulin effectively. There are two major forms of diabetes. Type 1 diabetes (T1D) or insulin-dependent diabetes mellitus (IDDM) results from the body's failure to produce enough insulin. The precise mechanism of IDDM is unknown, and hence there is no known preventive measure for it. On the other hand, T2D or non-insulin-dependent diabetes mellitus (NIDDM) is commonly preceded by insulin resistance manifested by increased insulin release to maintain glucose homeostasis (Kahn, Hull, & Utzschneider, 2006).

The etiology of T2D has been suggested to be glucotoxicity, lipotoxicity and inflammation, which lead to insulin resistance