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Anti-diabetic effects of soluble and insoluble dietary fibre from deoiled cumin in low-dose streptozotocin and high glucose-fat diet-induced type 2 diabetic rats

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A B S T R A C T

The effects of soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) from deoiled cumin on low-dose streptozotocin and high glucose-fat-induced type 2 diabetes rats were examined. Male Wistar rats were divided into nine groups: control (non-diabetic, no SDF or IDF intake), model (diabetes only), metformin, high-dose SDF (5 g/kg body weight), middle-dose SDF (500 mg/kg body weight), low-dose SDF (250 mg/kg body weight), high-dose IDF (5 g/kg body weight), middle-dose IDF (500 mg/kg body weight), and low-dose IDF (250 mg/kg body weight). SDF treatments, in particular, middle-dose SDF for 4 weeks, induced better regulation of blood glucose, insulin, hormones, and liver lipid metabolism in diabetic rats, accompanied by increased levels of short-chain fatty acids in colon and decreased fatty degeneration of liver. Our results collectively support the therapeutic potential of SDF from deoiled cumin in type 2 diabetes.

1. Introduction

Diabetes mellitus is a common condition arising from defects in the production or action of insulin. An estimated 380 million or more individuals suffer from diabetes worldwide, leading to more than 2.9 million deaths each year, which are projected to rise over the next 30 years (Yadav, Morris, Harding, Ang, & Adams, 2009). Diabetes, especially type 2 diabetes, is strongly associated with hyperglycaemia, heart problems, kidney disease, impaired vision, limb loss, and general poor health (Galisteo, Duarte, & Zarzuelo, 2008; Simpson & Morris, 2014). A number of drugs currently prescribed for type 2 diabetes cause undesirable side-effects. One therapeutic strategy may be to initially prevent the onset of type 2 diabetes by imposing diets that can slow down intestinal absorption of glucose,

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Chemical compounds: Glucose (PubChem CID: 5793); Cholesterol (PubChem CID: 5997); Triacylglycerol (PubChem CID: 71728460); Insulin (PubChem CID: 70678557); Leptin (PubChem CID: 90470904); Lactate (PubChem CID: 61503); Acetate (PubChem CID: 176); Streptozotocin (PubChem CID: 29327); Galactose (PubChem CID: 6306); Xylose (PubChem CID: 135191).

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resulting in a blunted postprandial glucose response. Consumption of these foods may additionally decrease the dose requirement of drugs, consequently reducing undesirable side-effects (Brockman, Chen, & Gallaher, 2012).

Specific polysaccharides from fruits, vegetables and cereals can effectively regulate colon cancer, obesity, cardiovascular diseases and type 2 diabetes (Adam et al., 2014; Erukainure et al., 2013; Holt et al., 2009; Maxwell et al., 2016). Dietary fibre (DF), a category of natural polysaccharides, has been shown to decrease total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C) and triacylglycerol (TG) levels, alleviate insulin resistance, decrease postprandial blood glucose reaction, and inhibit inflammatory factors in obesity, type 2 diabetes and Zucker diabetic fatty (ZDF) rats (Galisteo et al., 2010; Toivonen et al., 2014; Weitkunat et al., 2015). However, previous studies on the anti-diabetic effects of DFs have mainly focused on vegetables, fruits and cereals, and total DF (TDF) or mixed DF. DFs obtained from different sources may be fermented in the large intestine to different degrees due to their specific components and different solubilities, leading to distinct metabolic effects (Galisteo et al., 2010; Weitkunat et al., 2015).

Deoiled cumin, generated after essential oil and oleoresin extraction from cumin (*Cuminum cyminum*), has not been commercially exploited and is generally discarded as waste. Earlier, our group showed that the purity of DF (84.18 g/100 g) obtained from deoiled cumin is higher than that of grape peel, cocoa, and carrot peel. Moreover, cumin DF modified by laccase and cellulase under high hydrostatic pressure (HHP) has excellent physicochemical and functional properties, including water swelling and oil adsorption capacities, as well as antioxidant activity. Modified cumin DF additionally exhibits better glucose adsorption capacity and α-amylase activity inhibition ratio. These two *in vitro* activities are particularly relevant for anti-diabetic activity, and higher than those of other DFs from peach, oat, and carrot (Ma & Mu, 2016; Ma et al., 2015).

To the best of our knowledge, no reports to date have focused on the effects of DFs from deoiled cumin on type 2 diabetes *in vivo*. Earlier research on the effects of DFs on metabolic syndrome revealed that pectin and xylan increase glucose concentrations in type 1 diabetes (Toivonen et al., 2014). In contrast, Wu, Shi, Wang, & Wang (2016) recently reported that pectin and xylan polysaccharides reduce glucose intake, fasting blood glucose and postprandial glucose after a carbohydrate-rich meal through various mechanisms, such as β-cell protection, inhibition of activities of glucose metabolism-related enzymes or regulation of insulin-related pathways. Guar gum has been reported to lower body weight and TC in obese mice, compared to oat insoluble DF (IDF) (Isken, Klaus, Osterhoff, Pfeiffer, & Weickert, 2010). However, the effects of soluble DF (SDF) and IDF on type 2 diabetes have not been established as of yet.

In the present study, we investigated the effects of different doses of SDF and IDF isolated from modified deoiled cumin DF on body weight, food intake, plasma biochemical parameters, liver lipids, short-chain fatty acids (SCFA), and histology in type 2 diabetic rats using an experimental rat model of low-dose streptozotocin (STZ) and high glucose-fat diet-induced diabetes. Our collective findings clearly support the therapeutic potential of DF from deoiled cumin on type 2 diabetes.

2. Materials and methods

2.1. Materials

Cumin (Dunyu No. 1 cultivar) seeds were acquired from Dunhuang Seed Co., Ltd. (Gansu, China), ground, and passed through a 40-mesh sieve. The obtained cumin powder (moisture content 7.0–8.0%) was stored in aluminium foil bags at 4 °C until use.

2.2. SDF and IDF preparation

SDF and IDF were extracted from cumin according to an earlier published method (Ma et al., 2015). Briefly, essential oil and oleoresin were extracted from cumin powder as described by Bligh and Dyer (1959) to obtain the deoiled cumin. Then, protein was hydrolysed by Alcalase 2.4 L (Novozymes, Bagsvaerd, Denmark) after shear emulsification to obtain deoiled cumin DF. The purity of deoiled cumin DF was 84.18 g/100 g, and the residual cumin was composed of starch (1.02 g/100 g), protein (3.64 g/100 g), fat (1.09 g/100 g), and ash (5.69 g/100 g) (Ma & Mu, 2016). The DF was further treated with laccase and cellulase using an HHP machine (L2-600/2, Huataisenmiao Biological Engineering Technology Co., Ltd, Tianjin, China) to obtain a modified DF mixture. The mixture was heated in boiling water for 15 min to terminate enzymatic hydrolysis and allowed to cool to room temperature, followed by centrifugation at 7000 × g for 15 min. The resulting precipitate was freeze-dried at −60 °C (FD5-3, American International Group, New York, NY, USA) to obtain the IDF fraction. The supernatant was collected and mixed with 95% ethanol at a 1:4 ratio at room temperature for 2 h and centrifuged at 7000 × g for 15 min, and the resulting precipitate was freeze-dried at −60 °C to obtain the SDF fraction. The purities of SDF and IDF from deoiled cumin were 90.7 and 80.5%, respectively. Five monosaccharides and two uronic acids were identified in the fractions via high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD), as reported by Mei, Mu, and Han (2010) (Table 1). SDF was mainly composed of galactose (30.47%), arabinose (27.02%), and xylose (16.54%), while the main components of IDF were xylose (43.07%), followed by arabinose (32.99%) and galactose (9.59%). The galacturonic and glucuronic acid contents of SDF were higher than those of IDF.

Table 1 – Monosaccharides and uronic acids composition (%, dry weight) of soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) from deoiled cumin.

Monosaccharides and uronic acids	SDF	IDF
Rhamnose	13.20 ± 0.50^a	3.96 ± 0.11^b
Arabinose	27.02 ± 0.45^b	32.99 ± 0.51^a
Galactose	30.47 ± 0.56^a	9.59 ± 0.12^b
Glucose	3.57 ± 0.08^b	7.89 ± 0.32^a
Xylose	16.54 ± 0.41^b	43.07 ± 0.87^a
Galacturonic acid	5.98 ± 0.09^a	1.38 ± 0.04^b
Glucuronic acid	3.22 ± 0.11^a	1.11 ± 0.07^b

Data were expressed by means ± standard deviation (SD). Values in the same row with different letters are significantly different, $p < 0.05$.