Resistant starch and diabetes pdf

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia due to defective insulin secretion, action or both (1). The diagnostic criteria for diabetes include fasting plasma glucose (FPG) ≥7.0 mmol/L (2), glycated hemoglobin (HbA1c) ≥6.5% (2–4), 2-h plasma glucose (2hPG) in a 75 g oral glucose tolerance test (OGTT) ≥11.1 mmol/L (2) or random PG ≥11.1 mmol/L. Meanwhile, pre-diabetes refers to impaired fasting glucose (IFG) of 6.1–6.9 mmol/L (5), impaired glucose tolerance (IGT)/2hPG in a 75 g OGTT of 7.8–11.0 mmol/L (5) or HbA1c of 6.0% to 6.4% (6), each of which places individuals at high risk of developing diabetes and its complications (7). A recent study by Khan and his team (8) presented the epidemiology of type 2 diabetes mellitus (T2DM) in terms of the global burden of disease and forecasted trends. The study showed that T2DM continues to be the leading cause of human suffering and deaths as it continues to increase in prevalence and incidence. This phenomenon continues, and there are no sights for reduction despite efforts in clinical care, research and public health interventions (8). Globally, it was recognized that diets low in whole grains, nuts, seeds and fruits were the leading dietary risks, especially in developing countries where globalization and emerging supermarkets increase access to processed, salt-laden, high-fat and sugar-added food products. Consequently, the attractiveness in line with low prices and higher accessibility led to decreased intake of whole grains, fruits and vegetables. In addition, poor dietary control and a sedentary lifestyle contribute to higher BMI that further elevates the associated risks (9). The nutritional recommendation based on FAO/WHO states that the acceptable macronutrient distribution range should be within 55–75% of net energy for carbohydrates, 10% for sugar components, while dietary fiber intake requirements differ with 38 g and 25 g for men and women, respectively (10). Several published findings have highlighted the association of high fiber and grains intake toward lower risk of both obesity and diabetes. However, the usual dietary pattern does not meet the recommended quantity, and hence it was suggested to include an additional grain-fibrous food for a more enhanced approach in managing metabolic conditions, such as diabetes (11–13). Starch is the predominant form of carbohydrate and is categorized as rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) determined based on their digestion rate. SDS seems to be slowly digested within the small intestines, whereas RDS tends to elevate glucose levels rapidly in the blood upon consumption. On the other hand, RS is undigested in the small intestines and usually fermented in the colon (14). Several studies have shown that RS is a linear molecule of α-1,4-D-glucan, derived from the retrograded amylose fraction and has a relatively low molecular weight (1.2 × 105 Da) (15, 16). The chemical structure of α-1,4-D-glucan is shown in Figure 1 (17). Figure 1. Chemical structure of α-1,4-D-glucan [Obtained from: (17)]. RS is used widely as a functional ingredient, especially in foods containing high dietary fiber levels. These types of food are assumed to help prevent several pathologies such as colon cancer, diabetes, or obesity (18). It has been proposed that foods containing naturally occurring RS or foods modified to contain more RS may alter the postprandial glycemic response, prevent hypoglycemia, reduce hyperglycemia and explain differences in some foods' glycemic index (GI). Dietary supplementation of RS is one of the nutritional interventions practiced for metabolic disease (19). Bread, cooked cereals and pasta, vegetables, just-ripe bananas are several familiar food products that serve as natural as natural RS sources. Consumption of RS foods tends to resist digestion in the small intestines and reaches the large intestines for microbial fermentation (14, 20, 21). There are five types of RS based on their indigestible properties (RS1, RS2, RS3, RS4, and RS5) (16, 17). RS1 refers to physically entrapped starch within whole plant cells and food matrices (e.g., partly milled grains and seeds) where there is a physical barrier to amylolysis. The presence of intact cell walls contributes to the RS content of legumes. Extensive milling (and chewing) allows these starches to be more accessible and less resistant. RS2 comprises the poorly gelatinized and hydrolyzed granules by α-amylases from certain plants (e.g., raw potato and green banana, HAM). Retrograded starches constitute RS3, which includes cooked and cooled rice or potatoes. Meanwhile, RS4 is a group of chemically modified starches that can improve the functional characteristics of the starch. Amylose-lipid complex has been proposed as RS5 because high-amylose starch tends to be more resistant to enzyme hydrolysis than low-amylose starch. The amylose-lipid complex in starch granules increases their enzyme resistance by restricting the granule swelling during cooking. Although these modified starches are found widely in processed foods, neither their contribution to RS intakes nor their physiological effects have been extensively studied (22). RS has the advantage of having a less negative influence on the sensory properties of final products than traditional fibers, such as whole grains, bran or fruit fibers, which is very positive for consumer acceptability (23). Consumption of RS has resulted in changes in insulin sensitivity, IGT and satiety in healthy humans (24) and therefore has been hypothesized to have implications for glycemic control in individuals at risk of or with T2DM. Among the five types, RS2 and RS3 were the most common form utilized for interventions, especially in evaluating their effects on blood lipids, GI and colon cancer (24, 25). RS-based diets are one of the nutritional interventions practiced for metabolic disease control, and these include common food sources such as bread, cooked cereals and pasta, vegetables and just-ripe bananas. Despite the numerous interventions on evaluating RS effects on diabetic control, the findings seem to be limited to short-term studies and lack longer-term studies to prove the benefits of RS. Thus, in this review, we intend to explore the reported studies on RS diet interventions to further understand its importance as well as to investigate the possible effects exerted by various RS-based intervention studies among pre-diabetes and diabetes adults. Materials and Methods Search Strategy Original articles were searched in three databases (PubMed, Scopus and ScienceDirect) from the year 2011 to 2021 using the Medical subject heading (MeSH) terms "diabetes," crossed with the term "resistant starch." Publications with available abstracts were reviewed and limited to studies published in English. Papers on human and clinical trials related to diabetes were included. However, review articles, proceedings, letters to the editor, and in vitro and in vivo studies were excluded. Duplicate articles were eliminated. The study identification process and reasons for exclusion are illustrated in Figure 2. Figure 2. PRISMA flow diagram of literature search and selection process. Eligibility Criteria We included published intervention studies (defined as a randomized controlled trial, crossover study and quasi-experimental study) comparing markers of glucose metabolism for RS consumption. We included only human studies with adult participants aged at least 18 years old from both genders. Studies were included if they analyzed at least one of the biomarkers as mentioned earlier. Study Selection A pair of authors independently assessed the titles and abstracts during the initial screening. The difference in the initial assessment was resolved by a discussion leading to a consensus, with a third party serving as arbitrator if necessary. Each study was recorded as include, exclude or unclear. Full articles were retrieved for further assessment if recorded as include or unclear. Any disagreement was re-evaluated and re-assessed among the reviewers. Results The search resulted in 50 articles produced with a refined search based on the availability of full text, peer-reviewed articles and library collection access. Upon further assessment, only 24 full-text articles were relevant and included for final review (Table 1). All the related articles were printed out for further assessment of evidence-based to explore the effectiveness of RS as a potential antidiabetic agent. Table 1. The potential health benefit effect of RS interventions on diabetic biomarkers. Discussion Table 1 was constructed based on available intervention studies on RS over the last decade. Although there are five types of RS, only three types have been clinically studied based on our search strategies from the three selected databases. HAM-RS2, an ingredient available to both food producers and consumers, was the usual form of RS2 used. HAM-RS2 is a bland, white substance with a small particle size comprised of 60% RS and 40% SDS (50). A randomized crossover study done by Bodinham and her colleagues on 12 overweight individuals reported significantly higher plasma insulin and C-peptide concentrations in individuals who consumed 40 g/d RS2 for 4 wks compared with the placebo (27). The process of insulin synthesis involves cleaving stages of C-peptide from proinsulin and is stored within secretory granules before its release in equimolar amounts with insulin into the bloodstream. C-peptide plays a vital role during this process by linking the A and B chains leading to precise folding and formation of interchain disulphide bonds (51). The presence of a higher level of both insulin and C-peptide assists the cells for better glucose absorption, blood sugar reduction and channeling glucose to the cells for energy synthesis. It is important to note that the circulating venous (or arterial) fasting insulin concentrations are about 18–90 pmol/L in healthy LN individuals (52). However, no changes were reported to either bodyweight or habitual food intake of the subjects in the study by Bodinham and team (26). In another crossover study done by the same group of researchers on individuals with well-controlled T2DM, RS2 consumption resulted in significantly lower postprandial glucose concentrations ($p < 0.05$) without any effect on hepatic, peripheral insulin sensitivity or HbA1c levels (27). Several biochemical abnormalities were observed in insulin and glucagon secretion, uptake and suppression of hepatic glucose production, and uptake of peripheral glucose among diabetic individuals that led to higher and prolonged postprandial glucose (PPG) excursions when compared with non-diabetic individuals (53). Generally, PPG accounted for ~80% of HbA1c when HbA1c was

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