

Review

From plate to pancreas: exploring the link between food and type 2 diabetes

Amal Elrherabi^{1*}, Mohamed Bouhrim^{2,3}, Mohamed Bnouham⁴

¹ Pharmacology Unit, Laboratory of Bioresources, Biotechnology, Ethnopharmacology and Health, Faculty of Medicine and Pharmacy, Mohammed First University, Oujda, Morocco

² Laboratory of Biological Engineering, Team of Functional and Pathological Biology, Faculty of Sciences and Technology, University Sultan Moulay Slimane, Beni Mellal, Morocco

³ Laboratories TBC, Laboratory of Pharmacology, Pharmacokinetics and Clinical Pharmacy, Faculty of Pharmacy, University of Lille, Lille, France

⁴ Laboratory of Bioresources, Biotechnology, Ethnopharmacology and Health, Faculty of Sciences, Mohammed First University, Oujda, Morocco

* Correspondence to: Amal Elrherabi, Pharmacology Unit, Laboratory of Bioresources, Biotechnology, Ethnopharmacology and Health, Faculty of Medicine and Pharmacy, Mohammed First University, Oujda, Morocco. E-mail: amal.rhe96@gmail.com

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Abstract

Diabetes mellitus is a prevalent chronic condition marked by persistent hyperglycemia due to impaired insulin production or utilization. Dietary factors significantly contribute to the development and progression of type 2 diabetes. This review critically examines current literature to explore the relationship between specific dietary components and diabetes risk. Foods implicated in diabetes pathophysiology, such as processed meats, refined carbohydrates, sugar-sweetened beverages, and ultra-processed foods, were analyzed for their biochemical and metabolic impacts. Processed meats containing nitrite-nitrates and N-nitrosamines were found to elevate advanced glycation end products (AGEs), increasing diabetes risk. Refined carbohydrates and sugar-sweetened beverages exacerbate hyperglycemia and insulin resistance by raising calorie density and reducing dietary fiber. Ultra-processed foods, rich in hydrogenated fats and synthetic additives, promote insulin resistance and obesity. High salt intake induces leptin resistance, while excessive sugar consumption triggers hyperinsulinemia and weight gain. Conversely, reducing these dietary risks and promoting balanced diets with whole grains, fiber-rich foods, and unsaturated fats can lower diabetes risk. Targeted dietary modifications, including limiting processed and ultra-processed foods, and adopting healthy dietary patterns, play a pivotal role in preventing and managing type 2 diabetes. These findings underscore the critical importance of dietary interventions in mitigating diabetes prevalence and complications.

Keywords: diabetes, food, insulin resistance, carbohydrates, meat products

Introduction

The increasing global prevalence of obesity and diabetes, along with their related cardiometabolic (CM) risk factors, has become a significant public health issue over the last three decades [1].

Diabetes Mellitus (DM), commonly referred to as just diabetes, is a metabolic disorder characterized by elevated blood sugar levels due to issues with insulin secretion or action, leading to disruptions in carbohydrate, fat, and protein metabolism [2]. Type 2 dia-

betes is among the five leading causes of mortality in several developed nations, with increasing worries over its alarming rates in multiple developing nations [3]. In the year 2021, approximately 8 million individuals worldwide received a diagnosis of Type 1 diabetes, among these, approximately 1.5 million were under 20 years old, 5.4 million were aged between 20 and 59, and 1.6 million were 60 years or older. There were 0.5 million new cases reported during the year, and around 35,000 individuals who showed symptoms but remained undiagnosed passed away within a year [4].



Mexico and the USA are the nations with the highest incidence, exhibiting a prevalence of 10.8% and 10.3% respectively [5]. As per the WHO's general guidelines for diagnosing Diabetes Mellitus, T1DM is identified by the destruction of the beta cells, leading to a total shortage of insulin. This disorder can present in two forms, either autoimmune or idiopathic [6]. Type 2 Diabetes Mellitus (T2DM) is a developed form of diabetes which may vary in nature, ranging from a major insulin resistance with a limited insulin shortage to a significant secretory issue with or without insulin resistance [7].

The long-term effects of type 2 diabetes can have significant impacts on various bodily systems. One such complication is retinopathy, which can lead to vision loss. Additionally, nephropathy can result in kidney failure and peripheral neuropathy can cause foot ulcers and even gangrene. Furthermore, autonomic neuropathy can affect sexual function and heart rhythm. However, the greatest threat to those with diabetes comes from macrovascular issues such as heart attack and stroke. People with type 2 diabetes face a 2–4 times higher risk of dying from heart disease compared to those without the condition. This chronic illness can also shorten life expectancy by 5–10 years for middle-aged individuals [8]. Type 2 diabetes arises due to a mixture of genetic susceptibility, habits that increase risk, and environmental factors [9]. The risk of T2D progression can be reduced by 40% through a healthy diet and increased exercise, as evidenced by large-scale intervention studies. T2D is classified as a disease linked to diet and lifestyle habits [10]. Given T2DM's impact on the world's health, it's crucial to examine and tackle potential causes of the disease, particularly those that can be altered through lifestyle changes such as dietary habits. A poor diet, characterized by limited consumption of nutritious foods such as fruits, vegetables, whole grains, nuts, and legumes and excessive intake of harmful foods like added sugar, processed meats, refined grains, and fried foods, increases the likelihood of T2DM [11]. The composition of one's diet can have an impact on the onset of type 2 diabetes by altering body weight [12].

In this review, we've scientifically examined the link between diet and diabetes induction, seeking to increase awareness of the mechanistic aspects of this metabolic disorder. Our aim is to equip individuals with evidence-based insights into how specific foods influence insulin resistance and blood sugar regulation. While individual articles discuss these foods separately, our review consolidates this knowledge into a

single resource, offering a comprehensive view of their collective impact on diabetes prevention.

Material and methods

A comprehensive literature search was conducted using electronic databases, including PubMed, Scopus, Web of Science, and Google Scholar, to identify relevant studies examining the association between dietary factors and the risk of type 2 diabetes mellitus as shown in Figure 1. The search strategy combined keywords related to diabetes (“type 2 diabetes”, “insulin resistance”, “hyperglycemia”) with dietary components (“processed meat”, “refined carbohydrates”, “sugar-sweetened beverages”, “ultra-processed foods”, “dietary fat”, “salt”, and “fried foods”). Original research articles, systematic reviews, and meta-analyses published in English were considered. The reference lists of retrieved articles were also manually screened for additional relevant studies.

Food groups and risk of diabetes mellitus

Processed meat

Many research studies have found a significant link between the consumption of red meat and an increased vulnerability to developing Type 2 diabetes. A meta-analysis of 13 studies that have been made available in the “European Journal of Epidemiology”, found that for every 100-gram portion of red meat consumed per day, The chance of Type 2 diabetes occurrence was amplified by 19% [13]. Two recent studies in the U.S. found that consuming processed meat frequently is associated with an increased likelihood of Type 2 diabetes in both males and females [14]. Processed red meat can contain various chemicals because of conservation, wrapping, and culinary methods, this includes the addition of nitrates and nitrites during the processing stage, as well as the creation of heterocyclic amines and polycyclic aromatic hydrocarbons when red meat is cooked at high temperatures for a prolonged period [15]. These chemicals can transform into N-nitrosamines, Which have been discovered to have a toxic effect on pancreatic β -cells [16]. In addition, the cooking or processing of meat can lead to the formation of advanced glycation and lipoxidation end products, these factors have been associated with insulin resistance and complications related to diabetes in studies conducted on animals [17], and human studies [18, 19]. Despite this, red meat is a

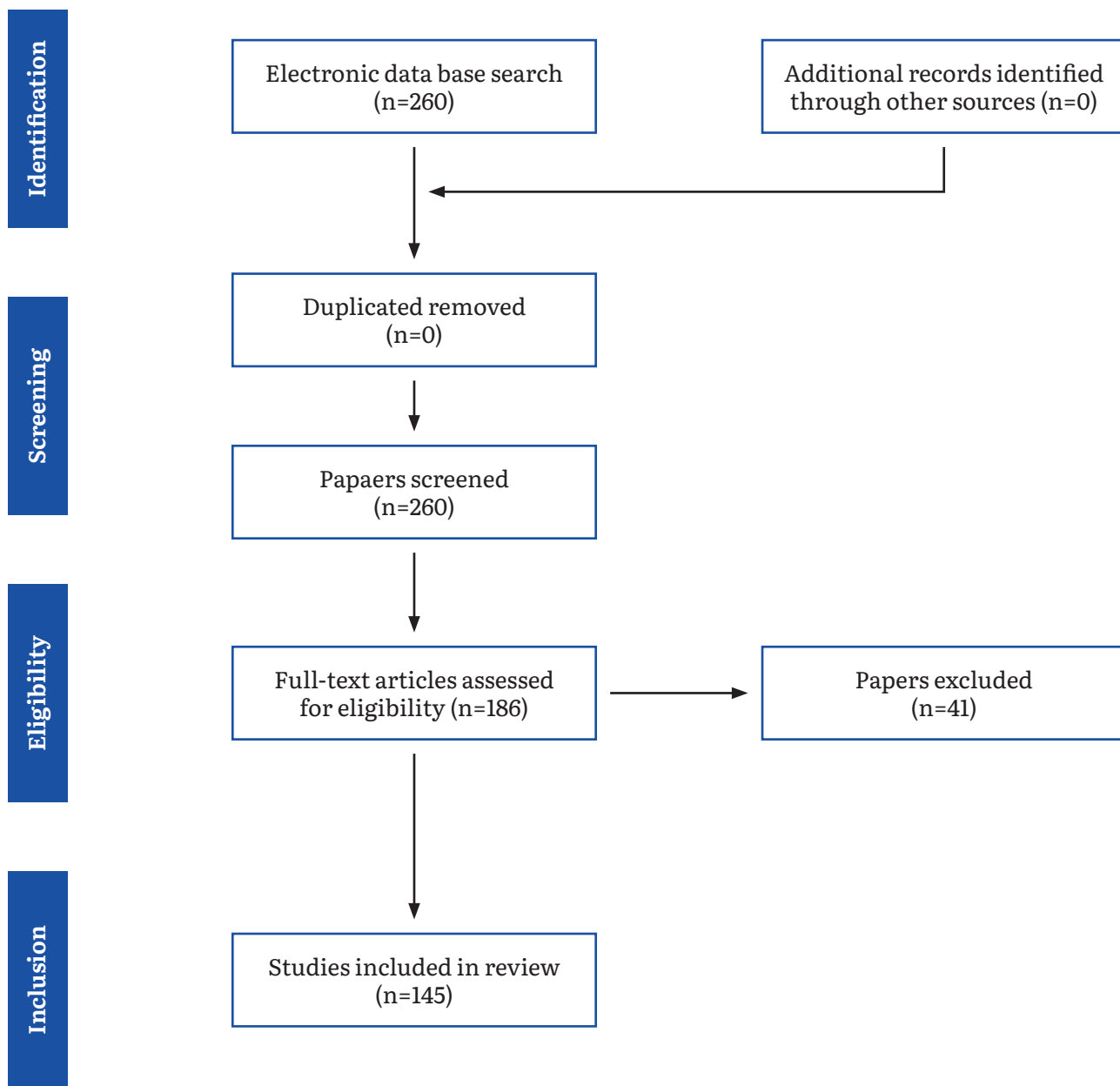


Figure 1: PRISMA flow diagram.

significant contributor of saturated fat, animal protein, heme iron and cholesterol to the diet. Research has indicated that certain fats found in red meat may significantly contribute to the onset of type 2 diabetes [20].

Cow’s milk

Ecological studies have established connections between cow’s milk (CM) consumption and the frequency of type 1 diabetes in terms of geography and time [21, 22]. An analysis of 9 regions in Italy found a strong association between the incidence rates of diabetes in children aged 0 to 14 months and their consumption of cow’s milk, the correlation coefficient was calculated to be 50.84 for fluid milk consumption [21]. Gerstein’s

meta-analysis of 13 studies showed that people who consumed a diet based on cow’s milk (CM) before the age of 4 months faced a 1.5 times higher risk of developing diabetes [23]. The idea was raised that cow’s milk protein is not the reason for the relationship, rather the increased weight gain in infants fed with formula may be confounding the results [24].

Eggs

Three major prospective cohort researches of US men and women in the dose-response analysis found that consuming one egg per day was linked to a 14% greater incidence of type 2 diabetes (T2D), after taking into account lifestyle elements and meals that are

frequently eaten with eggs. Asian and European research, however, did not show any correlation [25]. A previous meta-analysis of prospective cohort studies found that individuals who consumed one egg or more per day had a 42% higher risk of developing diabetes as compared to those who did not consume eggs [26]. This meta-analysis was limited to five cohort studies and only included research conducted in the United States. Additionally, no assessment was made of the relationship between egg consumption and diabetes risk [27]. Egg consumption habits can be a reason for these discrepancies, because eggs are frequently consumed with sugary beverages, red or processed meat, and refined carbs in the United States, egg intake is indicative of adherence to a Western dietary pattern [28]. According to the Physicians' Health Study, there appears to be a correlation between egg consumption and diabetes prevalence. The study found that the prevalence of diabetes was 1.9%, 2.5%, 2.7%, 3.1%, 7.3%, and 6.8% for individuals consuming <1/wk, 1/wk, 2-4/wk, 5-6/wk, 1/d, and ≥2/d, respectively. In comparison to individuals who did not consume eggs, those who consumed ≥7 eggs/wk had a hazard ratio of 1.58 (1.25-2.01) for diabetes in men in the Physicians' Health Study, and 1.77 (1.28-2.43) in women in the Women's Health Study [29].

Fatty acid

Lovejoy and DiGirolamo found a positive association between insulin sensitivity and total dietary fat, which was determined from postload insulin and glucose measurements [30]. The composition of dietary fat may impact the onset of type 2 diabetes, as indicated by another prospective study among elderly women [31]. Rats fed diets containing high levels of fat were observed to have reduced insulin sensitivity. Research demonstrated that rats consuming a high-fat diet with a fat content accounting for 59% of their energy intake, exhibited lower insulin sensitivity when compared to rats fed a low-fat diet with a fat content of only 12% of their energy intake [32]. The risk of developing diabetes within 1-3 years was forecasted by the amount of fat consumed in the diet, as determined by a 24-hour recall [33]. There are several proposed mechanisms by which saturated fatty acids may enhance diabetes's risk. One possibility is that saturated fat may increase insulin resistance, which is a significant risk factor for type 2 diabetes [34]. When cells in the body do not respond appropriately to insulin, it results in insulin resistance, leading to high blood sugar levels. Saturated fat has been shown to increase insulin resistance in both human and animal studies [35].

Refined carbohydrates

Recent studies indicate that consuming a large amount of refined carbohydrates may raise the likelihood of developing insulin resistance [36, 37]. The refining process alters the composition of carbohydrates, thereby decreasing their nutritional quality, for instance, when whole grains are transformed into white flour, it leads to a significant increase in calorie density by more than 10%, a drastic reduction in dietary fiber by 80%, and a substantial loss of dietary protein by nearly 30% [38]. The refining process strips away many of the key elements, resulting in a dietary substance that is almost entirely composed of starchy carbohydrates and with fewer essential nutrients [39].

Total potato

Out of 13 researches investigating the link between potato consumption and T2D risk, 8 were conducted in Western countries. Of those, 7 found a positive correlation, however only 4 were statistically significant. The summary of the Western population's effect estimates revealed a 19% rise in the risk of T2D with increased total potato consumption (RR: 1.19 [1.06, 1.34]) [40]. Out of the five studies that investigated the link between consuming Potatoes that have been cooked through methods such as baking, boiling, or mashing and T2D risk, two of them found a statistically positive association [41]. Of the six studies that looked at the correlation between French fries and fried potatoes and the risk of T2D, two found a significant elevation in risk [42]. The Western researches found a significant increase in the risk ratio for T2D (RR: 1.33 [1.03, 1.70]), when comparing extreme intake categories, The consumption of an extra 80g of fried potatoes or French fries per day showed a statistically significant 34% increase in the risk of T2D (RR: 1.34 [1.24, 1.46]) [40].

White bread

Iranian researchers conducted a study to investigate the effect of consuming whole wheat bread instead of white wheat bread on risk factors in individuals with pre-diabetes. The study found that there was a clear link between consuming white bread and higher levels of waist circumference (WC), blood sugar (BS 120), hemoglobin A1C (HbA1C), triglycerides (TG) and systolic blood pressure (SBP) [43].

White rice

Several studies in both the US and Asia have found a link between regularly consuming refined carbohydrates like white rice and a higher risk of developing

diabetes [44, 45]. The Shanghai Women's Health Study examined the association between carbohydrate intake and health outcomes. The study found that those who consumed high levels of carbohydrates, as measured by glycemic load, had a 34% higher risk of a health outcome compared to those who consumed low levels of carbohydrates. Additionally, the study found that those who consumed high amounts of white rice, the primary dietary contributor to glycemic load in the study population, had a 78% higher risk of a health outcome compared to those who consumed low amounts of white rice. The results were reported with 95% confidence intervals [44]. White rice is a common food in China and is known for its elevated glycemic index load, which is a measure of the overall impact of carbohydrates in the diet [46]. Studies have shown that consuming elevated levels of this dietary glycemic load, which is mainly sourced from white rice, can increase type 2 diabetes risk. This link between white rice consumption and diabetes has been noted in numerous epidemiological researches [44, 47, 48].

Sugar

There is evidence to suggest that a high sugar intake may elevate the risk of developing type 2 diabetes (World Health Organization. (2015). Sugars intake for adults and children [49]. After consuming sugar, it is absorbed into the bloodstream and triggers the pancreas to produce insulin. If sugar is regularly consumed in large amounts, the pancreas may become overworked and unable to keep up with the demand for insulin. This can cause insulin resistance and to type 2 diabetes [50]. In addition to its effects on insulin production and insulin resistance, a high sugar intake may also contribute to the development of type 2 diabetes by causing weight gain. The consumption of high quantities of sugar can result in weight gain, which in turn increases the likelihood of developing type 2 diabetes [51]. Carbohydrate quality can affect how quickly they are digested and how quickly blood glucose levels respond [52]. Simple carbohydrates seem to be more easily accessible for rapid absorption by the intestines than complex carbohydrates, and as a result, they cause a higher and quicker increase in postprandial plasma glucose and insulin responses [53]. To measure the glycemic responses caused by carbohydrates in various foods, the glycemic index idea was created [54]. Considering animal experiments [54], and brief human experiments [55], have looked at the relationship between the glycemic index and the incidence of type 2 diabetes, despite the fact that some evidence points to a possible role

for high-glycemic-index diets in the onset of diabetes in women [44, 56], and in men [57]. However, Insulin secretion is decreased whenever the rate of glucose absorption is reduced [55].

Salt

The correlation between salt consumption, risk factors for diabetes, and complications related to diabetes is significant. Based on epidemiological studies on salt consumption, it is evident that the global population consumes excessive amounts of salt. This overconsumption of salt is linked to dysregulated blood glucose levels and insulin resistance [58]. Consuming a diet high in salt over a prolonged period has been linked to insulin resistance and metabolic syndrome. Miguel Lanasa and his team have discovered that an excessive salt intake triggers the aldose reductase-fructokinase route in both hypothalamus and the liver, causing the body to produce its own fructose and resulting in the evolution of leptin resistance [59]. In an earlier investigation, scientists gave mice a drinking solution containing 1% hypertonic NaCl for 30 weeks and found that the mice on the Salt-rich diet had increased endogenous fructose production, which resulted in obesity, metabolic syndrome, and elevated blood pressure, despite also higher osmolality and elevated levels of sorbitol and fructose. Mice treated with salt exhibited leptin resistance, which drives hyperphagia through mechanisms that take place after the process of fructose metabolism. The scientists examined information gathered from a cohort study comprising 13,000 healthy adults in Japan to evaluate the applicability of their discoveries to humans. Their results indicated that increased initial intake of salt could anticipate the onset of metabolic syndrome, which includes diabetes and fatty liver, even after controlling for overall caloric consumption [60].

The body undergoes significant metabolic changes prior to the onset of diabetes [61]. Metabolic syndrome (MetS) can be attributed, at least in part, to the improper release of cytokines from adipose tissue [62]. Metabolic syndrome increases the risk of type 2 diabetes by five-fold and often leads to complications in the majority of individuals with diabetes [63]. Metabolic syndrome is a multifaceted disorder characterized by a combination of various factors, such as high blood pressure and abnormal triglycerids and cholesterol levels, abdominal obesity, elevated fasting blood sugar, and reduced insulin sensitivity [62]. As metabolic risk factors increase, the sensitivity of blood pressure to salt gradually rises. This correlation between metabolic syndrome and salt

sensitivity persisted even after individuals with hypertension were excluded from the analysis, indicating that those with metabolic syndrome are more susceptible to developing salt sensitivity [64].

According to a study, individuals who add salt to pre-prepared meals without tasting, or when there is insufficient salt, have approximately twice the risk of emerging type 2 diabetes mellitus compared to those who never add salt to pre-prepared meals. In a study of 932 Finnish men and 1003 women, conducted over an average follow-up period of 18 years, it was found that a greater intake of salt (measured by 24-hour urinary sodium) was linked to an elevated risk of type 2 diabetes, even after controlling for confounding variables such as physical activity, obesity, and hypertension [65].

Ultra-processed food

Industrial formulations known as UPF are produced through the utilization of compounds that have been extracted, produced or derived from comestibles or comestible constituents [66]. UPFs generally consist of a mix of five or more constituents that are sourced from high-yield food substances. These ingredients may include uncommon components like hydrogenated fat and corn syrup with a high fructose content, as well as synthetic additives like sugar substitutes, pigments, emulsifying agents, and preservatives that are not typically found in a kitchen setting [55]. Ultra-processed foods typically have a nutrient composition that is linked to a higher risk of type 2 diabetes, including high levels of calories, trans and saturated fatty acids, sucrose, and sodium along with reduced amounts of dietary fiber, vitamins and minerals, when compared to unprocessed foods [55]. A 10% increase in the consumption of processed foods results in a 15% higher risk of developing type 2 diabetes, as per a study that revealed a direct and proportional relationship between the intake of ultra-processed foods and the risk of T2DM [67]. Research from two separate cohort studies – one carried out in the Netherlands and the other in Brazil – have shown that a 10% rise in the intake of ultra-processed foods is linked to a 33% and 13% respectively greater risk of developing type 2 diabetes. Additionally, two other cohort studies, one in Spain and the other in the United Kingdom, have found that individuals who had a greater quantity of ultra-processed foods experienced a 53% and 44% elevated likelihood of developing T2DM respectively [66]. The excessive intake of ultra-processed foods, which are rich in saturated fatty acids, sugar, and salt, is believed to be a significant contributing factor to the rising global epidemics of obesity and

diabetes [66]. According to a study that followed a group of 104,707 adults in France, there was a 13% increase in the risk of developing type 2 diabetes with each 10% increment in the proportion of ultra-processed foods in the diet (with a risk range of 1.01–1.27) [68]. Participants in the UK-based cohort who consumed the most ultra-processed foods had a 44% increased risk of developing T2D over a 4 to 5-year period, compared to those with the lowest intake. Additionally, there was a 12% rise in the risk of T2D for every 10-percentage-point increase in ultra-processed food consumption [69]. Elevating the proportion of ultra-processed comestibles in the diet leads to higher consumption of added sugars and saturated fatty acids, while reducing the amount of dietary fiber and protein in the overall diet [70]. Research has also revealed that ultra-processed foods have an increased impact on blood sugar levels, but do not lead to the same level of satiety as unprocessed alternatives [71]. The researchers proposed that the correlation between ultra-processed food consumption and diabetes may be explained by the fact that consuming excessive amounts of salt (>2.3 g/d) can trigger the hypothalamus and liver's aldose reductase-fructokinase pathway [72]. The activation of the aldose reductase-fructokinase pathway that may occur with excessive salt intake can result in greater production of fructose within the body and heightened resistance to the hormone leptin, both of which have been linked to insulin resistance [59].

Sugar-sweetened beverages

There is evidence to suggest that drinking sugar-sweetened beverages could heighten the risk of developing type 2 diabetes. One mechanism by which this may occur is through the effect of sugar-sweetened beverages on body weight gain. Several studies have found an association between higher intake of sugar-sweetened beverages and increased weight gain [51]. Weight gain is a risk factor for developing type 2 diabetes [49]. In a prospective study of African American women. Compared to women that consumed only about one soft drink per month, women who drank two or more beverages per day experienced a 24% increase in occurrence. Similar results were found for sugary fruit drinks, where a 31% rise was shown for daily use of two or more drinks compared to the monthly consumption of less than one drink [73]. Carbonated soft drinks, isotonic beverages, energy drinks, sweetened tea, and fruit drinks are examples of sugar-sweetened beverages having no nutritional value [74]. Excessive intake of sugary beverages was linked to a higher risk of type

2 diabetes mellitus (T2DM) and insulin resistance in a number of recent epidemiological studies [75].

The intake of sugar-sweetened beverages before pregnancy was significantly and favorably linked with the risk of gestational diabetes mellitus. Women who drank more than 5 servings of sugar-sweetened per week had a 22% higher chance of developing gestational diabetes mellitus than those who consumed less than one serving per month [76]. However, men were not affected by the enhanced danger of T2DM incidence caused by the intake of sugar-sweetened beverages [77].

Fried-food

Cooking food by frying is a complicated process that alters the fatty acid composition of the food, while the oils utilized during frying augment the food's energy density and decrease its water content [78]. In addition to its high-energy content, regular consumption of fried food is often viewed as a sign of an unhealthy lifestyle and poor dietary habits [79, 80]. Studies have demonstrated that consuming fried foods is linked to an elevated risk of developing type 2 diabetes [81]. In Western countries, especially in fast-food restaurants, frying is a commonly used cooking method, with fried-chicken products and French fries making up a significant portion of the food products offered for sale. Through polymerization, oxidation, and hydrogenation processes, frying modifies both the food being cooked and the oil it is cooked in. When oils are used repeatedly, they undergo deterioration, resulting in changes in the fatty acid composition and increased absorption of other oil degradation products into the fried foods [82, 83]. There have been previous reports indicating that certain frequently used food items for frying, including red meat and potatoes, are positively linked with an elevated risk of type 2 diabetes [84]. A more robust connection between the consumption of fried food and the risk of T2D was discovered when individuals consumed such food outside of their homes compared to when they consumed it at home. There are various possible reasons for this observation. One of the reasons may be that oils tend to degrade during frying, especially when reused, which may occur more often in settings outside of one's home. Another possible explanation could be that restaurant meals typically have larger portion sizes [85] and higher sodium content [86] than meals prepared at home. Typically, the ingredients of French fries include white potatoes and partially hydrogenated oils that contain trans-fat. Our cohort study revealed a positive association between the consumption of trans fats and an increased

likelihood of developing type 2 diabetes [87]. Consuming fried food outside the home is more strongly linked to an increased risk of T2D compared to eating fried food at home, and there could be various reasons for this association. One possible explanation is that oils tend to degrade more rapidly during frying, especially when they are reused, and this practice may be more prevalent in restaurants than in households. Another contributing factor could be the larger portion sizes typically served in restaurants [85], and higher sodium contents [86].

Discussion

Type 2 diabetes is influenced by both genetic and environmental factors. Individuals with a family history of the disease are at a greater risk of developing it [88]. Although diet and nutrition are commonly considered to have a significant impact on the development of Type II diabetes mellitus, there is currently no clear consensus on specific dietary factors that directly contribute to the disease [20]. The makeup of one's diet can impact the onset of type 2 diabetes by impacting body weight. Despite this correlation, there is a lack of comprehensive information from well-designed randomized trials in the available literature. Research, including both animal experiments and clinical studies, has consistently demonstrated a strong connection between dietary factors, especially fat and calorie consumption, and excessive body weight [87]. However, studies conducted on diet and obesity in population groups have had inconsistent outcomes due to various factors, such as poor study design and inaccurate dietary data measurement [12]. Many studies have demonstrated a correlation between diabetes and overall dietary fat. 24-hour recall assessments showed that the total amount of dietary fat in subjects with impaired glucose tolerance (IGT) predicted whether they would develop diabetes within 1 to 3 years [33].

Although meat consumption is often viewed as a factor that increases the risk of metabolic diseases, a research suggests that the impact and degree of risk can differ based on both the type of meat consumed and the particular health outcome being studied [89]. In terms of major components, processed meats differ significantly from unprocessed meats mainly due to the presence of preservatives, particularly sodium. In comparison to unprocessed meats, processed meats typically contain approximately four times more sodium and 50 percent more nitrates per gram [89]. In addition to

sodium, processed meats also commonly contain other preservatives, such as nitrates and their byproducts, including peroxy nitrite. Scientific research has shown that these preservatives can contribute to the development of health problems like endothelial dysfunction, atherosclerosis, and insulin resistance [84].

Epidemiological data about a relationship between milk consumption and type 2 diabetes in adult individuals are rare [90]. Numerous studies [84] have reported a correlation between early exposure to cow's milk proteins and an increased risk of type 1 diabetes mellitus, although not all studies [91] have found this association. When consumed by individuals with a certain genetic susceptibility, Bovine serum albumin has the potential to trigger an immune response. This response may then cause a reaction with a protein found on the surface of beta cells, known as p69 [84]. The destruction of beta cells is thought to be facilitated by the expression of this protein on their surface. This is because it makes the cells susceptible to attack by the immune system, leading to their destruction, which can lead to the onset of diabetes mellitus [92].

Some studies conducted on animals have indicated that a diet high in cholesterol may result in increased levels of fasting plasma glucose, as well as causing hyperinsulinemia and impaired glucose tolerance [84]. Based on research, there is evidence to suggest that elevated serum cholesterol levels may be linked to increased islet cholesterol content, potentially leading to impaired β cell function through a reduction in glucose-stimulated insulin secretion [84]. There is evidence from research studies to suggest that dietary cholesterol intake may be linked to chronic, low-grade inflammation, which is considered to be a contributing factor in the development of insulin resistance and type 2 diabetes [93]. However, the available data on the association between egg consumption and the risk of developing diabetes are very limited and inconsistent [94]. In contrast to the aforementioned studies, a research study conducted on Japanese subjects found no significant correlation between egg consumption and the risk of developing diabetes [95]. These discrepancies in findings may be attributed to variations in study populations, analytical techniques, and dietary habits related to egg consumption and cooking methods, such as boiling or frying.

Unlike the findings from animal studies, research on human subjects has not consistently shown negative effects of high-fat diets on insulin sensitivity. Although some earlier studies, all of which were less than one month in duration, indicated a decrease in insulin

sensitivity among patients consuming a high-fat diet [96]. The interpretation of these results, however, is challenging due to several factors. For instance, the diets were not randomized in their order, there were notable weaknesses in the methods used to measure insulin sensitivity, or there were significant differences in the diets apart from the variance in fat content [97]. Out of these studies, only one revealed a reduction in insulin sensitivity among patients who consumed a high-fat diet (50% energy) when compared to those who consumed a low-fat diet (20% energy). This could potentially be attributed to the significant difference in the quantity of saturated fat between the two diets [98]. Despite limited evidence to support the notion that dietary cholesterol has a detrimental impact on glucose metabolism, research has found a positive correlation between cholesterol consumption and both hyperglycemia and the risk of developing diabetes [99]. Since cholesterol is exclusively found in animal products, these correlations may indicate a negative impact of a dietary pattern with high consumption of meat and eggs or an unknown constituent within animal products. Accordingly, the connection between meat consumption and mortality from diabetes, as recorded on death certificates, which was observed in the Seven Day Adventist study, is noteworthy [100]. Foods with a high glycemic index (GI) are high in carbohydrates that are rapidly metabolized and result in a rapid increase in blood sugar levels after eating. On the other hand, foods with a low GI contain carbohydrates that are broken down slowly, leading to a more gradual increase in blood sugar levels that decline more slowly over time [101]. Glycemic load (GL) is a measure that takes into account both the type of carbohydrates in a food (determined by the glycemic index or GI) and the amount of carbohydrates present. It furnishes a comprehensive depiction of how carbohydrates in a given food affect blood sugar levels [56]. The connection between glycemic load (GL) and glycemic index (GI) and their impact on the risk of developing diabetes has yet to be fully established. Some studies have shown an association between high GL or GI and an increased risk of diabetes, but the evidence is not conclusive [45, 56]. Various animal studies have investigated the effects of different types of starch on the onset of insulin resistance. These studies discovered that rats fed an amylopectin-rich diet were more prone to insulin resistance compared to their counterparts who were fed an isocaloric diet with amylose [102].

Regrettably, the existing food environment hinders the adoption and maintenance of healthy dietary

habits, making it difficult for individuals to improve the quality of their diets. To facilitate the adoption of healthy dietary patterns among the broader population and steer dietary decisions, it may be useful to concentrate on particular food groups and specify their intake levels that are associated with the lowest risk of type 2 diabetes. To date, long-term randomized trials investigating the prevention of type 2 diabetes through lifestyle interventions have primarily assessed the efficacy of a multifaceted nutritional approach, which primarily targets weight reduction [103]. The current recommendation to consume diets that are rich in healthy plant-based foods (such as whole grains, fruits, vegetables, nuts, legumes, and non-tropical vegetable oils), while reducing the intake of less healthy items (such as fruit juices, sweetened beverages, refined grains, potatoes, and pastries) is supported by various epidemiological evidence. This includes both long-term prospective observational studies and short-term trials on intermediate outcomes. Such studies have generated substantial data, reinforcing the benefits of adopting such diets to achieve better health outcomes [104]. While recommendations for animal-based foods are typically vague and limited to a general reduction, it's worth noting that not all animal-based foods are equal. There are significant variations in their fat content and fatty acid profile (such as the presence of saturated vs. unsaturated fat), and certain animal-based foods contain bioactive components that have positive impacts on health. For instance, fermented dairy products are one example of animal-based foods that contain beneficial bioactive components [105].

Conclusion

In conclusion, diabetes remains a pervasive global health concern, impacting millions of lives and posing a significant burden on healthcare systems worldwide. This chronic disease, characterized by elevated blood glucose levels, can give rise to a host of debilitating complications. Our exploration of the role of specific foods in diabetes development underscores the importance of dietary choices in this context. Red and processed meats, cow's milk, eggs, fatty acids, refined carbohydrates, fried foods, sugar-sweetened beverages, and ultra-processed foods have all been implicated as potential contributors to diabetes, either through insulin resistance, weight gain, or other mechanisms. Moreover, the adverse effects of salt and sugar on metabolic processes cannot be overlooked. Therefore, it is

imperative to exercise caution and moderation when consuming these foods, especially for individuals seeking to prevent diabetes or manage the condition. In conjunction with a balanced diet, regular physical activity remains a cornerstone of diabetes prevention and management, offering a path towards improved health and a reduced risk of this prevalent and debilitating disease.

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Conflict of interest

The authors declare no conflict of interest.

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