Review Article

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Planting a path to kidney health: The vegetarian diet and diabetic nephropathy

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Abstract: About 40% of people with diabetes experience diabetic nephropathy (DN), which is the main cause of renal problems. The aberrant urine albumin excretion rate, diabetic glomerular lesions, and a reduction in glomerular filtration rate are its defining characteristics. Numerous studies have found a strong link between eating animal protein and conditions like glucagon activation, insulin resistance, proteinuria, microalbuminuria, and the worsening of kidney problems in diabetic individuals. A vegan diet, which forgoes all animal products including leather and other non-edibles like fish, shellfish, and insects as well as dairy, eggs, and honey, has demonstrated significant benefits. It has been connected to enhanced insulin sensitivity, less glucagon activation, a decreased risk of developing chronic kidney disease (CKD), and a slowed rate of DN progression. According to several studies, avoiding animal products and switching to plant-based protein sources can be a better nutritional plan than simply limiting dietary protein. This change may prove very helpful in reducing the risk of kidney and cardiovascular illnesses, especially for those who have diabetes and severe insulin resistance in addition to CKD. A vegan diet contains considerable benefits for those with diabetes and CKD, acting as a brake on the advancement of DN and renal failure, according to the literature evaluation done for this study. Nevertheless, more interventional studies involving humans are needed to elucidate the processes underlying the increased insulin sensitivity brought on by vegan diets. It is also advised to conduct more research to fully explore the effectiveness and security of vegan diets in people with diabetes and DN.

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1 Introduction

Diabetic nephropathy (DN), a debilitating complication arising from diabetes mellitus, remains a significant global health concern, contributing to the escalating burden of chronic kidney disease (CKD) and end-stage renal disease (ESRD). Its severe impact on public health is evident, with DN accounting for approximately one-third of all ESRD cases [1,2]. As diabetes prevalence rises, healthcare systems worldwide face a substantial challenge in managing DN effectively. The condition develops gradually over years of poorly controlled blood glucose concentrations in individuals with diabetes, causing damage to the kidneys' intricate filtering units called glomeruli, resulting in renal dysfunction and structural changes. A hallmark sign is proteinuria, indicating compromised kidney function. Traditionally, managing DN has focused on blood glucose control, blood pressure management, and the use of renin-angiotensin-aldosterone system inhibitors to slow its progression. However, emerging evidence suggests that dietary interventions can complement standard therapeutic approaches and play a pivotal role in prevention and management [3,4]. A well-designed diet tailored to individual needs can significantly impact factors associated with the condition's pathogenesis and progression. Given DN's high prevalence, substantial healthcare costs, and profound impact on affected individuals' quality of life, exploring innovative approaches, including dietary interventions, is crucial. Understanding the molecular mechanisms involved in DN provides insights into how dietary choices can affect blood glucose regulation, blood pressure control, and overall kidney function. Certain dietary components can exacerbate or ameliorate kidney damage in those with DN. Various dietary patterns, such as low-glycemic-index diets, plant-based diets like vegetarian and Mediterranean diets, and sodium restriction, have been investigated for their potential benefits.

Clinical studies exploring the effects of dietary interventions on DN outcomes provide valuable insights into improving kidney function and slowing disease progression [5,6]. Evidence-based guidelines offer healthcare professionals valuable recommendations for dietary management, including macronutrient composition, sodium and phosphorus restriction, fluid management, and the inclusion of specific foods and nutrients with potential renoprotective effects. With a comprehensive understanding of the role of a well-structured diet in DN management, healthcare providers can optimize patient care and improve long-term outcomes [7,8]. This review was aimed to study the correlation between Vegetarian diet and DN.

2 Role of diet in DN management

2.1 Dietary factors affecting kidney health

Diet plays a crucial role in maintaining kidney health and managing the progression of kidney disease, including conditions like DN. Adopting a well-balanced diet that considers various factors, such as protein intake, sodium restriction, fluid management, potassium and phosphorus monitoring, and the consumption of healthy carbohydrates, mono- and poly-unsaturated fats, and antioxidant-rich foods, can be highly beneficial for individuals with kidney conditions [9,10]. A personalized dietary approach, tailored to each individual's medical history and kidney function, can help optimize kidney health and overall well-being. Regular consultation with healthcare professionals, particularly registered dietitians, is vital for developing and implementing appropriate dietary strategies to promote kidney health and prevent complications associated with kidney disease. Understanding the impact of key dietary components on kidney function is crucial for devising effective dietary approaches that support kidney health [11]. The dietary elements that have a significant impact on kidney health as per various studies are listed below:

2.1.1 Protein intake

The amount of protein consumed is a critical factor to consider for maintaining kidney health. While protein is essential for the body's functions, consuming excessive protein can be difficult for the kidneys, especially in individuals with impaired kidney function [11,12]. High-protein diets may lead to heightened glomerular pressure and hyperfiltration, which could potentially speed up the advancement of kidney disease. For individuals with DN, it is advisable to follow a moderate protein intake (0.6–0.8 g/kg/day) that is customized to their specific kidney function and medical background to alleviate the burden on the kidneys [13].

2.1.2 Sodium (Salt) intake

Consuming excessive amounts of sodium can elevate blood pressure and result in fluid retention, placing additional strain on the kidneys. High blood pressure is a major risk factor for kidney disease, making it crucial to reduce sodium intake to maintain kidney health. Reducing the consumption of processed and packaged foods, which tend to be high in sodium, and opting for herbs and spices as flavor enhancers instead of salt can effectively lower sodium intake [14,15].

2.1.3 Fluid intake

Adequate fluid management plays a vital role in promoting kidney health, particularly for individuals with kidney disease. Ensuring the appropriate intake of fluids helps maintain fluid balance and prevents issues like dehydration or fluid overload. In more advanced stages of kidney disease, it may become necessary to restrict fluid intake to prevent complications such as edema [15,16].

2.1.4 Potassium and phosphorus

Individuals with compromised kidney function must pay close attention to their potassium and phosphorus intake. Maintaining proper levels of these minerals is crucial as elevated potassium, or hyperkalemia, can cause harmful heart rhythm disturbances, and high phosphorus levels can have adverse effects on bone health [13,17]. Foods that are rich in potassium and phosphorus, like bananas and dairy products, may need to be restricted in the diet [18].

2.1.5 Carbohydrate quality

The amount and type of carbohydrates consumed can have a major impact on kidney health, particularly in diabetics. High glycemic index foods can cause rapid rises in the concentration of glucose in the blood, resulting in glycation and oxidative stress, both of which may contribute to kidney damage [19,20]. Choosing carbohydrates with a low glycemic index, such as whole grains and legumes, can help regulate blood sugar concentrations and reduce the risk of renal problems in people with diabetes [21].

2.1.6 Fats and fatty acids

Mono- and poly-unsaturated fats, like those present in nuts, seeds, avocados, and olive oil, are advantageous for maintaining kidney health. Conversely, a diet rich in saturated and trans-fats can lead to inflammation and cardiovascular issues, which can also affect kidney function. Striking a balanced consumption of mono- and poly-unsaturated fats is crucial for promoting overall kidney well-being [22–24].

2.1.7 Antioxidants and anti-inflammatory foods

Consuming diets abundant in antioxidants and anti-inflammatory compounds like vitamins C and E, beta-carotene, and polyphenols can provide protection against oxidative stress and inflammation in the kidneys. Fruits, vegetables, nuts, and seeds are excellent sources of these beneficial nutrients, contributing to enhanced kidney health [17,25,26].

2.2 Impact of dietary protein on DN

The relationship between dietary protein and DN is a complex matter that necessitates careful attention and customization. While protein is crucial for overall health, excessive intake (more than 0.6–0.8 g/kg/day) can place an added burden on compromised kidneys. Striking the right balance between protein intake and kidney health is paramount in managing DN through diet [12,27,28]. Tailored dietary recommendations, taking into account individual medical history and kidney function, can optimize protein consumption and enhance kidney health in individuals with DN. Regular monitoring and consultation with healthcare professionals, including registered dietitians, are vital in implementing suitable dietary strategies to support kidney health and overall well-being for those with DN. As protein metabolism inherently strains the kidneys, the role of dietary protein in DN management warrants careful consideration and personalization [7,29,30]. The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (KDOQI), Kidney Disease Improving Global Outcomes (KDIGO), and the American Diabetes Association (ADA) have extensively reviewed the literature on dietary protein intake and diabetic kidney disease (DKD). These organizations have assessed the evidence base to formulate clinical guidelines regarding this essential macronutrient. According to KDOQI guidelines, individuals with DKD stages 1–4 are advised to aim for a protein intake of 0.8 g/kg/day, supported by grade B evidence. KDIGO guidelines propose a dietary protein intake of 0.8 g/kg/day for adults with diabetes and a glomerular filtration rate of <30 mL/min/1.73 m^2, provided appropriate education is given, and this recommendation is supported by Grade 2c evidence. On the other hand, the ADA recommends maintaining the usual dietary protein intake, supported by Grade A evidence. Both KDOQI and KDIGO caution against high protein intake, defining it as >20% of kcal from protein and >1.3 g/kg/day for individuals with CKD respectively [31].

2.2.1 Protein metabolism and kidney function

Protein consumption is essential for a range of bodily functions, such as tissue repair, enzyme production, and immune support. Nevertheless, when dietary protein is broken down, it generates waste products like urea and creatinine, which the kidneys must filter and eliminate. In individuals with DN, impaired kidney function diminishes the kidneys' capacity to efficiently clear these waste products, possibly resulting in additional kidney damage [32–34].

2.2.2 Proteinuria and glomerular hyperfiltration

Consuming too much protein can place a greater burden on the kidneys, causing glomerular hyperfiltration. This condition results in an increased blood flow through the glomeruli, the kidney's filtering units, potentially leading to kidney damage and proteinuria. Proteinuria, characterized by an excess of protein in the urine, is a distinctive feature of DN and signifies ongoing kidney injury [35–37].

2.2.3 Balancing protein intake

It is crucial to discover the right balance of protein intake for individuals with DN. While sufficient protein is necessary to sustain muscle mass and overall well-being, excessive consumption can worsen kidney damage. Achieving a balance between preserving muscle mass and not placing excessive strain on the kidneys is a vital aspect of managing the diet in DN [32,38].

2.2.4 Dietary protein restriction

Historically, individuals with DN were often advised to follow a low-protein diet to ease the kidneys' burden. Nevertheless, recent studies have provided varied findings regarding the advantages of strict protein restriction.

While some research indicates that very low-protein diets may decelerate the decline in kidney function, other studies have not demonstrated substantial benefits or have raised concerns about potential nutritional deficiencies linked to such diets [11,12,39].

2.2.5 Individualization of protein intake

Determining the ideal protein intake for individuals with DN should be customized, considering various factors such as the stage of kidney disease, the extent of proteinuria, the presence of other medical conditions, and the individual's nutritional status. A personalized approach, overseen by a registered dietitian or healthcare professional, can effectively establish the suitable protein level for each person [40,41].

2.2.6 High-quality protein sources

Opting for superior protein sources holds significant importance for individuals with DN. Protein derived from plant-based sources like legumes, nuts, seeds, and whole grains can be advantageous due to their reduced phosphorus content and potential anti-inflammatory effects. Moreover, incorporating essential amino acids into the diet can aid in preserving muscle mass without overwhelming the kidneys with excessive waste products [41–43].

3 Role of carbohydrates and fats in kidney health

The significance of carbohydrates and fats in maintaining kidney health should not be underestimated, especially for individuals with kidney disease like DN. Selecting the appropriate types and amounts of carbohydrates and fats is crucial in promoting overall well-being and managing disease progression [44,45]. Prioritizing a diet rich in low-glycemic-index carbohydrates, high-quality fats, and sufficient fiber can aid in stabilizing blood glucose concentrations, enhancing lipid profiles, and reducing inflammation, all of which support kidney health and help prevent kidney complications. As with any dietary considerations for kidney health, individualization and regular monitoring by healthcare professionals, including registered dietitians, are essential to optimize nutritional strategies and enhance outcomes for individuals with kidney disease [46–48].

3.1 Role of carbohydrates in kidney health

3.1.1 Glycemic control

Carbohydrates serve as the body's main energy source, but their effect on blood glucose concentrations is a crucial consideration for individuals with kidney disease, including DN [49–51]. Foods with a high glycemic index can lead to swift increases in blood glucose concentrations, resulting in heightened glycation and oxidative stress, potentially contributing to kidney damage. Thus, opting for carbohydrates with a low glycemic index, such as whole grains, legumes, and non-starchy vegetables, can aid in stabilizing blood glucose concentrations and decreasing the likelihood of kidney complications in diabetes [52–54].

3.1.2 Energy balance

Ensuring a proper equilibrium between energy intake and expenditure is crucial for maintaining overall kidney health. Consuming excessive carbohydrates and other macronutrients can contribute to weight gain and obesity, both of which are risk factors for kidney disease. Managing carbohydrate intake to meet energy requirements while avoiding excess calories can play a role in supporting kidney health [55,56].

3.1.3 Dietary fiber

Incorporating high-fiber carbohydrates like whole grains, fruits, and vegetables into the diet provides several health advantages, such as promoting better bowel function and lowering cholesterol levels. Sufficient fiber intake can also aid in managing blood glucose concentrations and decreasing the risk of developing kidney stones, a prevalent complication of kidney disease [57,58].

3.2 Role of fats in kidney health

3.2.1 Cardiovascular health

The role of fats in cardiovascular health is closely tied to kidney health. Individuals with kidney disease face an increased risk of cardiovascular issues like heart disease and stroke. Incorporating mono- and poly-unsaturated fats, such as those found in nuts, seeds, avocados, and olive

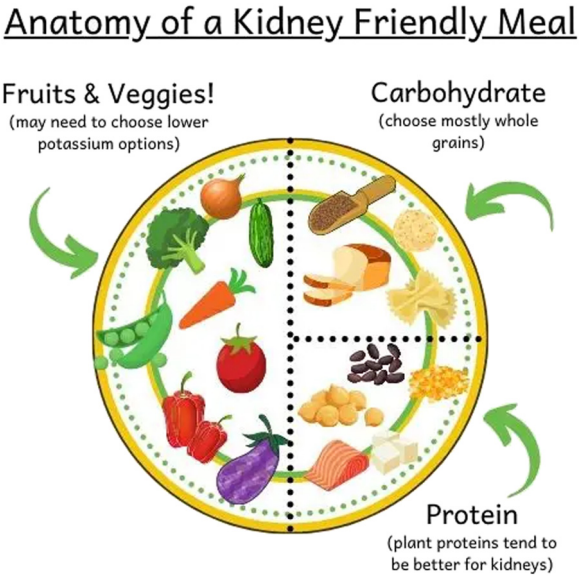
oil, can assist in reducing inflammation, enhancing blood lipid profiles, and providing protection against cardiovascular complications [59–61].

3.2.2 Inflammation

CKD is linked to heightened systemic inflammation, which can exacerbate kidney damage. Consuming saturated and trans-fats commonly found in processed and fried foods can worsen inflammation and negatively impact kidney health. Substituting these unhealthy fats with healthier alternatives can aid in reducing inflammation and enhancing kidney function [62,63].

3.2.3 Nutrient absorption

Fats play a crucial role in facilitating the absorption of fat-soluble vitamins (A, D, E, and K) and specific essential nutrients. It is important to have an adequate intake of fats to ensure the proper absorption of these vital nutrients, which are essential for overall health, including kidney health [64–66].



3.3 Micronutrients and DN

Micronutrients play a critical role in managing DN by supporting kidney health, reducing oxidative stress and inflammation, and optimizing metabolic processes. Ensuring an adequate intake of vitamins and minerals through a balanced diet or, if necessary, through supplementation, can help enhance kidney function, lower the risk of complications, and improve overall well-being in individuals with DN [67,68]. However, it is vital to collaborate with healthcare professionals, including registered dietitians, to ensure that individual micronutrient needs are met and to monitor for potential interactions or adverse effects related to supplementation. Several micronutrients have been extensively studied for their potential impacts on kidney health, inflammation, oxidative stress, and glucose regulation [68,69].

3.3.1 Vitamin D

Vitamin D plays a vital role in regulating calcium and phosphorus, supporting bone health, and boosting immune function. In individuals with DN, vitamin D deficiency is prevalent and has been linked to the progression of kidney disease and a higher risk of cardiovascular complications. Ensuring sufficient levels of vitamin D in diet is crucial for promoting overall kidney health, as well as reducing inflammation and oxidative stress [70,71].

3.3.2 Vitamin E

Vitamin E serves as a potent antioxidant, shielding cells from oxidative harm. Oxidative stress is a significant factor contributing to kidney injury in DN. Animal studies have shown promising results regarding the potential of vitamin E supplementation in diminishing oxidative stress and enhancing kidney function. However, further research is required to determine its clinical relevance in humans [72].

3.3.3 Vitamin C

Vitamin C contributes to shielding against oxidative stress and inflammation and serves like an antioxidant. In cases of DN, vitamin C may aid in diminishing the production of reactive oxygen species, which can lead to kidney damage. Ensuring sufficient vitamin C levels is crucial for supporting overall kidney health and immune function [73–75].

3.3.4 B Vitamins

B vitamins, such as B1 (thiamine), B6 (pyridoxine), and B12 (cobalamin), play vital roles in diverse metabolic

processes. In DN, individuals may experience modified metabolism and heightened excretion of these vitamins, resulting in deficiencies. Introducing B vitamin supplementation may help rectify deficiencies and bolster kidney function [76–78].

3.3.5 Magnesium

Magnesium is indispensable for numerous enzymatic reactions within the body and plays a role in glucose metabolism and blood pressure regulation. DN is linked to magnesium deficiency, which could worsen kidney damage and contribute to cardiovascular complications. Maintaining adequate magnesium intake can assist in promoting kidney health and enhancing glucose control [79–82].

3.3.6 Zinc

Zinc is a micronutrient essential for immune function and antioxidative processes. DN is connected to higher levels of oxidative stress and inflammation, and inadequate zinc concentrations in diet could aggravate these issues. Ensuring adequate zinc intake in diet can provide protection against kidney injury and enhance overall well-being [83,84].

3.3.7 Selenium

Selenium, a crucial trace mineral, serves as an antioxidant. In cases of DN, selenium deficiency has been linked to heightened oxidative stress and inflammation. Sufficient selenium intake can potentially aid in lessening kidney damage and enhancing antioxidant defenses [85–87].

3.4 Benefits of plant-based diets in diabetes and kidney disease

Plant-based diets, which prioritize the intake of whole, plant-derived foods while reducing or excluding animal products, have garnered considerable interest for their potential advantages in managing diabetes and kidney disease, including DN [13,17,88,89]. Numerous studies and clinical trials have underscored the favorable impacts of plant-based diets on various aspects of health, particularly in the management of diabetes and kidney conditions [89]. Here are some of the primary benefits of plant-based diets in diabetes and kidney disease:

3.4.1 Glycemic control

Plant-based diets, especially those abundant in whole grains, legumes, fruits, and vegetables, are often characterized by a lower glycemic index, leading to gradual and controlled rises in blood glucose concentrations. This attribute can be especially advantageous for individuals with diabetes, as it supports the stabilization of blood sugar levels and diminishes the likelihood of glycemic fluctuations, which may contribute to complications such as DN [13,17,90–96].

3.4.2 Blood pressure management

Hypertension, or high blood pressure, frequently arises as a complication of diabetes and stands as a major risk factor for kidney disease. Plant-based diets typically have reduced levels of sodium and saturated fats, both of which are recognized for elevating blood pressure. Moreover, these diets are abundant in potassium, which can aid in reducing blood pressure and enhancing kidney function [97,98].

3.4.3 Weight management

Since plant-based diets often contain fewer calories and saturated fat, they are advantageous for weight control and weight loss. For those with diabetes and kidney illness, maintaining a healthy weight is crucial since extra body weight can increase insulin resistance, blood pressure problems, and renal function [33,99].

3.4.4 Kidney health

Plant-based diets may offer kidney-protective benefits owing to their lower acid load compared to animal-based diets. High-acid diets can heighten the risk of acidosis and worsen kidney damage. Plant-based diets, especially those that prioritize fruits and vegetables, have been linked to reduced acid load and a decreased risk of kidney stone formation [99].

3.4.5 Antioxidant and anti-inflammatory properties

Plant-based diets are abundant in antioxidants and anti-inflammatory compounds like vitamins C and E, carotenoids, and polyphenols. These substances aid in neutralizing free radicals and diminishing inflammation, both of

which can play a role in kidney injury and complications related to diabetes [26,100].

3.4.6 Fiber content

Plant-based diets generally contain ample dietary fiber, which brings forth several health advantages. Fiber can aid in enhancing blood glucose control, lowering cholesterol levels, and supporting healthy gut function. Sufficient fiber intake is also linked to a decreased risk of developing kidney stones [17,101,102].

3.4.7 Lower risk of cardiovascular disease

Cardiovascular disease is a typical adverse outcome for those with diabetes and kidney disease. The consumption of a plant-based diet has been linked to a lower risk of cardiovascular events like heart attacks and strokes. Plant-based diets can improve blood lipid profiles, lower inflammation, and promote heart health, which can have a positive impact on cardiovascular health in those with diabetes and renal disease [103,104].

3.5 Vegetarian diet and DN

DN, a serious complication of diabetes, presents a considerable challenge to kidney health. Amidst the myriad strategies explored for managing diabetic complications, the vegetarian diet has emerged as a focal point of interest. Characterized by the exclusion of meat and often other animal products, this plant-centric approach is gaining attention for its potential benefits in preventing and managing DN. A vegetarian diet, abundant in fruits, vegetables, whole grains, legumes, nuts, and seeds, provides a nutrient-rich profile. The exclusion of red and processed meats aligns with a lower intake of saturated fats and cholesterol, characteristics that hold relevance in the context of diabetes and its complications [105–107]. One of the key mechanisms through which a vegetarian diet may impact DN is improved glycemic control. The high fiber content in plant-based foods contributes to the regulation of blood sugar levels, a critical factor in reducing the risk of hyperglycemia, which is intricately linked with diabetic complications.

Furthermore, the presence of antioxidants in fruits and vegetables within the vegetarian diet plays a pivotal role. Antioxidants act as scavengers for free radicals, mitigating oxidative stress, a significant contributor to the development and progression of DN. By providing a rich source of antioxidants, a vegetarian diet potentially offers protective effects against oxidative damage to renal tissues [108,109]. The lower intake of saturated fats and cholesterol inherent in a vegetarian diet also holds potential cardiovascular benefits. Given the intricate connection between cardiovascular health and DN, a heart-healthy diet becomes relevant in overall renal well-being. The vegetarian diet's capacity to improve lipid profiles and reduce inflammation adds another layer to its potential protective effects [2,110]. While scientific literature increasingly explores the relationship between a vegetarian diet and DN, it is crucial to acknowledge that research on this topic is still evolving. Not all studies demonstrate consistent results, and factors such as individual responses to dietary patterns, the specific composition of vegetarian diets, and the need for more robust, controlled trials warrant consideration for a comprehensive understanding [111,112].

A notable study published in the *Journal of Renal Nutrition* in 2019 investigated the dietary patterns of individuals with type two diabetes. This study revealed that adherence to a vegetarian diet was associated with a lower risk of developing DN. The findings, based on a large cohort, underscored the potential significance of plant-based dietary patterns in reducing the incidence of kidney complications in individuals with diabetes. However, amidst the promising aspects, it is essential to approach the adoption of a vegetarian diet with careful consideration. Achieving a nutrient-balanced vegetarian diet, particularly addressing concerns about protein intake, is crucial. Careful planning is necessary to ensure adequate protein, essential amino acids, and other nutrients. Supplementation, especially for vitamin B12, should be considered, as this vitamin is primarily found in animal products. Regular monitoring of nutritional status, blood glucose levels, and kidney function is advisable for individuals with DN following a vegetarian diet [2,113]. Individual responses to dietary interventions can vary, taking into account factors such as cultural preferences, socioeconomic status, and personal health goals. While the potential benefits of a vegetarian diet in the context of DN are promising, it is part of a broader approach to diabetes management. Lifestyle modifications, medication adherence, and regular medical monitoring remain integral components of an inclusive strategy [8,114]. The potential benefits of a vegetarian diet in preventing and managing DN are supported by emerging evidence. The emphasis on plant-based, nutrient-dense foods aligns with principles of healthy eating and may contribute to improved glycemic control, cardiovascular health, and antioxidant defense. However, more research, particularly randomized controlled trials, is needed to establish a clear cause-and-

effect relationship and formulate specific dietary recommendations. Individuals should approach a vegetarian diet with careful consideration, seeking guidance from healthcare professionals or registered dietitians to ensure nutritional adequacy and compatibility with overall health goals. The vegetarian diet shows promise as part of a comprehensive approach to diabetes management, with its potential benefits deserving further exploration and understanding [115,116].

3.6 Nutritional considerations for vegetarian diets in DN

When contemplating a vegetarian diet for individuals with DN, it is crucial to take into account several important nutritional factors to ensure that the diet is well-balanced and beneficial for kidney health. Paying proper attention to these aspects can help improve glycemic control, regulate blood pressure, and promote overall kidney function [117–119]. Here are some significant nutritional considerations for individuals with DN who adopt a vegetarian diet:

3.6.1 Protein quality and quantity

Sufficient protein consumption is vital for general well-being, but it is important to carefully manage the amount to prevent unnecessary strain on the kidneys [120]. For individuals with DN, it is advisable to opt for a moderate protein intake that meets their specific requirements. Focusing on high-quality plant-based protein sources, such as legumes (beans, lentils, peas), tofu, tempeh, seitan, and quinoa, is recommended. Incorporating a diverse range of protein sources can ensure the intake of all essential amino acids [121,122].

3.6.2 Carbohydrate quality and quantity

Opt for complex carbohydrates with a low glycemic index to maintain stable blood glucose concentrations. Excellent choices include whole grains, legumes, fruits, and non-starchy vegetables. It is essential to be mindful of portion sizes to effectively manage carbohydrate intake and prevent significant fluctuations in blood sugar levels [21,121,123].

3.6.3 Healthy fats

Incorporate healthy fat sources like avocados, nuts, seeds, and olive oil into the diet. These fats possess anti-inflammatory properties and can promote cardiovascular health, which is particularly important for individuals with DN [124,125].

3.6.4 Sodium restriction

High sodium intake can lead to fluid retention and hypertension, both of which can negatively impact kidney health. To avoid this, reduce the use of table salt and instead choose herbs, spices, and natural flavor enhancers to season your meals. It is also essential to limit the consumption of processed and packaged foods, as they often contain high levels of sodium [126–128].

3.6.5 Fluid intake

Adequate fluid management is crucial for individuals with kidney disease. Depending on the stage of DN and the level of kidney function, it may be necessary to limit fluid intake to prevent fluid overload and associated complications [129,130].

3.6.6 Micronutrient balance

Make sure to maintain sufficient intake of essential vitamins and minerals like vitamin D, vitamin B12, iron, zinc, magnesium, and potassium. Monitoring these nutrient levels and considering supplementation when needed can help prevent deficiencies and support overall health [131,132].

3.6.7 Phosphorus and potassium control

For those with advanced kidney disease, it is essential to keep a close eye on phosphorus and potassium intake. Certain plant-based foods like nuts, seeds, legumes, and specific fruits and vegetables have higher levels of these minerals. To manage their intake effectively, individuals may need to limit consumption or opt for lower-phosphorus and lower-potassium alternatives [133,134].

3.6.8 Regular monitoring

Consistently monitor kidney function and relevant laboratory indicators in collaboration with healthcare professionals, such as registered dietitians and nephrologists. This practice allows for the adjustment of dietary

recommendations as necessary to promote kidney health and overall nutritional well-being [134].

3.7 Challenges and limitations of a vegetarian diet for DN

Although a vegetarian diet can provide numerous advantages for individuals with DN, it also presents certain challenges and limitations that must be taken into account when adopting this dietary approach. Addressing these challenges is vital to maintain the nutritional adequacy and support for kidney health within the vegetarian diet [135]. Here are some of the key challenges and limitations to consider:

3.7.1 Protein quantity and quality

One major hurdle in adopting a vegetarian diet for individuals with DN is ensuring a sufficient and balanced intake of protein. Plant-based protein sources may not always offer all essential amino acids in ideal proportions. Careful meal planning is crucial to incorporate a variety of protein sources that meet individual protein requirements, supporting muscle health while avoiding excessive protein intake that could strain the kidneys [136].

3.7.2 Nutritional deficiencies

Unplanned vegetarian diets may pose a risk of specific nutritional deficiencies, including vitamin B12, iron, calcium, omega-3 fatty acids, and zinc. These deficiencies can have adverse effects on overall health and worsen kidney disease. It is crucial to regularly monitor nutrient levels and consider appropriate supplementation, if needed, to address these potential deficiencies [136,137].

3.7.3 Phosphorus and potassium management

Certain plant-based foods, such as legumes, nuts, seeds, and specific fruits and vegetables, naturally contain higher levels of phosphorus and potassium, which can pose challenges for individuals with advanced kidney disease. Effectively managing these mineral levels may involve restricting certain foods or opting for alternatives that are lower in phosphorus and potassium [137].

3.7.4 Sodium control

Reducing sodium intake is crucial for effectively managing blood pressure and fluid balance in individuals with kidney disease. Although plant-based diets generally have lower sodium content compared to omnivorous diets, certain processed vegetarian foods may still contain high levels of sodium. Careful reading of food labels and limiting sodium intake becomes essential in such cases [138].

3.7.5 Glycemic index and blood sugar management

Plant-based diets encompass carbohydrates with different glycemic indices. While whole grains, legumes, fruits, and vegetables are typically low glycemic, some carbohydrates and some fruits may have higher glycemic levels. Striking a balance in carbohydrate intake to ensure stable blood sugar levels is crucial in effectively managing diabetes [138].

3.7.6 Cultural and social factors

Embracing a vegetarian diet might encounter obstacles, particularly in cultural and social settings where meat holds significant importance in traditional dishes or gatherings. Ensuring a diverse range of vegetarian options and promoting acceptance can play a crucial role in sustaining adherence to the dietary choice [138].

3.7.7 Individual preferences and adherence

The effectiveness of any dietary intervention depends on the individual's ability to adhere to it and how well it aligns with their lifestyle. For certain people, adopting and sticking to a vegetarian diet can be difficult, potentially impacting its long-term sustainability [139].

3.7.8 Collaborative management

Introducing a vegetarian diet for DN necessitates close collaboration among the individual, healthcare professionals (including registered dietitians and nephrologists), and perhaps a certified diabetes educator. Regular monitoring and fine-tuning of the diet, tailored to individual requirements, are vital to optimize nutritional well-being and promote kidney health [139].

4 Conclusion

A vegetarian diet is important in the management of DN because it promotes glycemic control with low-glycemic-index plant-based foods, supports blood pressure management with reduced sodium intake and healthy fats, and reduces oxidative stress and inflammation with antioxidant-rich plant foods. A well-chosen plant-based protein reduces kidney strain while addressing potential vitamin deficits, thereby improving overall health. Furthermore, the cardiovascular benefits of a vegetarian diet contribute to kidney function protection in DN. Individualized planning and regular monitoring by healthcare specialists increase the effectiveness of the diet in promoting renal health and general well-being. Individuals with DN might potentially slow the advancement of the disease and lessen its complications by adopting a diet that promotes glucose control, kidney health, and general well-being. Collaboration with healthcare practitioners and qualified dietitians is critical for designing tailored dietary plans that enhance kidney health and improve the quality of life for people with DN.

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