Research and Application of Foods for Special Medical Purposes and Functional Foods in Meeting the Nutritional Needs of Patients with Kidney Disease

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Abstract. Kidney disease impact patients' health and quality of life. Acute kidney injury (AKI) is a life-threatening and critical illness, severely endangering patients' health and well-being. Chronic kidney disease (CKD) is also experiencing increasing mortality and morbidity, making it a significant global health issue. Kidney disease patients often experience energy depletion and nutrient loss. Providing appropriate nutritional support may improve the condition and also the prognosis. Therefore, medical nutrition therapy (MNT) plays a crucial role in the treatment of kidney disease. Oral nutritional supplements (ONS) offer advantages such as safety, effectiveness, and high patient compliance. Special medical foods and functional foods are two major ONS delivery vehicles. Therefore, analyzing, researching, and comparing the two nutritional delivery vehicles is of great significance to the nutrition and health of patients with kidney disease and can also provides insights and reference for the development and improvement of nutritional supplement products for kidney disease patients.

Keywords: Kidney disease, Nutrition; Foods for Special Medical; Functional Foods.

1. Introduction

The kidney plays an important role in removing metabolic waste and maintaining fluid balance and has the functions of secreting hormones, regulating blood pressure, and maintaining osmotic pressure in the body. Kidney disease refers to a variety of acute and chronic kidney diseases in clinical practice, as well as acute and chronic renal damage secondary to other systemic diseases, leading to renal failure. According to the definition of the Global Kidney Outcomes Organization, kidney disease can be divided into acute kidney injury (AKI) and chronic kidney disease (CKD). AKI is a critical disease that affects the patient's life and is particularly common in nephrology and ICU. Currently, CKD has become a serious global health problem. According to statistics, as of 2017, the global CKD prevalence was approximately 9.1%. China is the country with the largest number of CKD patients. Between 1990 and 2021, the incidence and mortality of CKD increased significantly. As of 2021, the number of CKD patients in China has reached 118.4 million [1]. Most CKD patients will eventually progress to the end-stage renal disease and need treatments such as renal dialysis and renal transplantation to maintain and achieve kidney function

One of the main functions of the kidney is to metabolize and excrete protein breakdown products. Therefore, various protein-related indicators (such as proteinuria) are also important criteria for judging many kidney diseases. In addition, protein is one of the most important nutrients for the human body. Therefore, protein plays an important role in understanding the patient's condition, controlling the progression of the disease, and solving the patient's nutritional problems. It is the nutrient that needs to be considered most in the diet and nutrition of patients with kidney disease.

Protein energy wasting (PEW) refers to the phenomenon of insufficient intake, excessive consumption or impaired utilization of protein and energy caused by chronic kidney disease or its complications, resulting in the loss of protein and energy in the body. For example, studies have shown that oral nutritional supplements (ONS), enteral or parenteral nutrition can effectively replenish the protein and energy reserves of patients with kidney disease, reduce complications caused by malnutrition, improve recovery efficiency, and effectively reduce medical costs [2].

Special medical foods are a key implementation tool for MNT. Special medical foods are specially processed and formulated to meet the special nutrient or dietary needs and play a role in nutritional support. They are suitable for different populations according to different clinical needs. Clinically, many special medical foods are targeted at early-stage CKD patients, using low-salt, low-protein, high-energy formulas to meet the nutritional needs of patients and have the effect of improving and delaying the disease. For patients with other kidney diseases, special medical foods are also used, but the demand for protein and other chemical substances has changed. For example, for patients with advanced CKD or dialysis-dependent CKD, in order to reduce the incidence and mortality of complications, special medical foods mainly control the intake of sodium and fluids, provide sufficient protein and high energy, etc.

Functional foods are called health foods in Europe and the United States, functional foods in Japan, and generally defined as health foods in China. Functional foods have similar functions and properties to fortified foods and adjust certain functions and serve specific populations through functional factors. Compared with drugs, functional foods are safer, can be obtained from daily diet, and are inexpensive. In addition, most functional foods have good anti-inflammatory, antioxidant, immune regulation, tumor inhibition and other health-promoting effects. Therefore, the role of functional foods in preventing and treating diseases has received more and more attention and has become a hot topic in nutrition research. At present, functional foods for kidney disease mainly emphasize restoring and improving kidney function by slowing down cell apoptosis or activating cells. In addition to research on common nutrients required by the human body, the world is also keen on extracting key substances or studying their active components from traditional or folk remedies for kidney disease to improve kidney function [3,4].

This article aims to summarize the types and mechanisms of kidney disease, common nutritional issues, and explore the key to solving nutritional problems and improving kidney function in kidney patients. It also explores the research and application of special medical foods in MNT and the supporting role of functional foods in MNT, discusses the nutritional mechanisms, and summarizes the nutritional needs and applications of kidney patients, providing support for future nutritional assurance and treatment of kidney patients.

2. Pathogenesis and Nutritional Issues of Jidney Disease

2.1. AKI

2.1.1. Classification and onset of AKI

AKI has a short onset time. After the cause is removed, renal function can be restored, achieving a good prognosis. AKI can be divided into three types: prerenal, renal parenchymal, and postrenal. Prerenal AKI is the most common. The kidney itself has normal structure. The cause of the disease is insufficient blood perfusion. If the kidney perfusion is restored in time, the renal function is reversible; renal parenchymal AKI is caused by damage to the kidney tissue itself, often accompanied by hematuria and proteinuria; postrenal AKI is caused by obstruction of the urinary tract, which hinders urine excretion and causes damage to the kidney due to pressure, often accompanied by low back pain and bladder swelling.

2.1.2. Nutritional issues in AKI

The main nutritional issues of AKI include abnormal protein metabolism, lipid metabolism disorders, insulin resistance and hyperglycemia, and acidosis. After the onset of the disease, the body enters a state of emergency, causing an increase in multiple hormones in the body, which in turn promote protein breakdown. At the same time, under the combined effects of other mechanisms such as inflammatory factors, patients experience trace element deficiencies, electrolyte imbalances, and acidosis [5].

2.2. CKD

2.2.1. Classification and pathogenesis of CKD

CKD refers to the structural and functional disorders of the kidneys caused by various reasons. It is a progressive disease with a long onset time and difficult to detect symptoms in the early stage, and it often develops into end-stage renal disease. In the Global Burden of Disease Study (GBD), CKD is divided into type 1 diabetic nephropathy, type 2 diabetic nephropathy, glomerulonephritis nephropathy, hypertensive nephropathy, other and unspecified nephropathy. Its onset is associated with many factors and other diseases. In China, high blood sugar, high BMI and high blood pressure are the top three risk factors for the burden of CKD [6]. At the same time, among the five subtypes mentioned above, type 2 diabetic nephropathy and hypertensive nephropathy are the two subtypes with the largest burden of death and disability-adjusted life years (DALYs) and have become a major global health problem [1]. As CKD progresses, kidney cells will eventually undergo apoptosis due to various abnormal mechanisms in the body, eventually causing damage to or even loss of kidney function.

2.2.2. Nutritional issues in CKD

CKD patients have a long course of illness and are very likely to suffer from chronic malnutrition. Therefore, in addition to paying attention to problems such as abnormal protein metabolism, energy deficiency, electrolyte imbalance and acidosis, as with acute kidney injury, more attention should be paid to the problems of trace element deficiency and renal anemia caused by long-term treatment and dietary restrictions. At the same time, as the patient's illness progresses, the apoptosis of kidney cells becomes increasingly serious, the number of active cells in the kidneys decreases, and kidney function weakens. Therefore, we should also focus on stimulating cell activity and pay attention to the nutrition required by the patient's body. In addition, the nutrition required for dialysis and non-dialysis patients is also different. In short, for patients with CKD, it is necessary to face the long-term nutritional problems caused by long-term progression and nutritional problems at different stages from a more macro perspective, and at the same time, improve the body function to address the problem of poor prognosis of patients.

3. Nutritional Mechanism and Principles of Special Medical Foods

The main goal of special medical foods is to meet the special nutritional needs of patients and maintain their clinical indicators. Therefore, when considering nutritional allocation, it is necessary to take a macro perspective and comprehensively consider the effects of major nutrients on the human body to solve the various nutritional problems faced by patients with special physical conditions. Generally, special medical foods for kidney disease must first consider nutrients such as protein and sodium that are more related to the nutritional problems of patients with kidney disease and also take into account nutrients such as vitamins that affect and regulate physiology.

3.1. Principles and Framework for the Use of Key Nutrients

3.1.1. Proteins

The renal function of patients with kidney disease is damaged, the filtration function is reduced, and the nitrogenous wastes such as urea and creatinine produced after protein metabolism will burden the kidneys. At the same time, proteinuria caused by kidney damage will further worsen the environment in the glomerulus and cause more serious damage to the kidneys. Meanwhile, patients in the kidney disease stage are also prone to negative nitrogen balance problems, which will cause insufficient energy in the body, affect normal physiological metabolism, and be detrimental to the body's recovery. Therefore, it is necessary to ensure that patients with kidney disease can take in enough nitrogen sources to ensure the normal storage of protein in the body and also to prevent excessive protein intake from further damaging the kidneys and reducing the accumulation of nitrogenous waste. At the same time, protein, as a basic nutrient, participates in complex and diverse biological reactions in the body. Therefore, it is difficult to use relatively simple indicators to formulate the same protein intake for patients with different conditions of kidney disease. The recommended protein intake usually changes according to the different stages and the patient's own physical condition (as seen in Table 1 for details).

Table 1. Daily protein intake recommended for patients with kidney disease in China, the United States, the European Union and other countries and regions [7-10].

Category	Patient Type	China (2021)	USA KDOQI/NKF (2020)	Australia KHA-CARI (2019)	Europe ESPEN (2021)
AKI	Non–RRT (mild–moderate)	1.2–1.5; may increase to 1.8–2.0 g/kg·d in severe catabolic or critical illness	1.2–2.0 g/kg·d (up to 2.5 g/kg·d in severe catabolism)	1.2–1.5 g/kg·d (adjusted to metabolic status)	Non-critical: 1.0–1.3 g/kg·d; Critical: 1.3–1.5 g/kg·d
AKI	With CRRT (CKRT)	1.5–2.0 g/kg·d (due to amino acid loss in effluent)	1.7–2.5 g/kg·d (high catabolic state)	1.5–2.0 g/kg·d	CKRT (critical): 1.5–1.7 g/kg·d
CKD	Non-dialysis (stable stage, incl. DM / non-DM)	0.6 g/kg·d (LPD) or 0.3–0.4 g/kg·d + keto acids (VLPD); for stable diabetes: 0.6 + 0.12 g/kg keto acids; avoid ≥ 1.3 g/kg	0.55–0.60 g/kg·d (or 0.28–0.43 + keto/AA supplement); diabetes: 0.6–0.8 g/kg·d	Not recommended ≤ 0.6 g/kg (IBW-based); recommend 0.75–1.0 g/kg·d	Hospitalized, non-critical CKD: 0.6–0.8 g/kg·d; if well-nourished, 1.0–1.3 g/kg·d
CKD	Dialysis (MHD / PD)	MHD: 1.0–1.2 g/kg·d (1.2–1.3 in acute catabolic states); PD: 1.0–1.2 if no residual kidney function (RKF), 0.8–1.0 if RKF present	1.0–1.2 g/kg·d (for both MHD and PD)	1.0–1.2 g/kg·d (maintenance dialysis phase)	Chronic KRT, non-critical: ~1.2 g/kg·d
CKD	Post-renal transplantation	Within 3 months post-surgery: 1.4 g/kg·d; > 3 months: 0.6–0.8 g/kg·d	Early postoperative: 1.3–1.5 g/kg·d; stable phase: 0.8 g/kg·d	Early postoperative: 1.2–1.5 g/kg·d; stable phase: 0.8–1.0 g/kg·d	—
CKD	Elderly CKD (≥ 65 years)	≥ 0.8 g/kg·d; frail/sarcopenic: 1.0–1.2 g/kg·d; avoid excessive restriction	≥ 0.8 g/kg·d (if malnutrition risk ↑, 1.0–1.2 g/kg·d)	0.8–1.0 g/kg·d; monitor for sarcopenia risk	Non-critical elderly CKD: ≥ 0.8 g/kg·d (emphasize adequate energy intake and PEW prevention)

RRT (Renal Replacement Therapy) includes all forms of kidney replacement therapies such as HD, PD, and CRRT (also known as CKRT, Continuous Kidney Replacement Therapy).

Protein intake recommendations for patients with kidney disease in various national guidelines reflect a general trend toward acute increases in protein intake, chronic restriction, and stable protein intake. Patients with AKI are in a hypercatabolic state and require higher protein intake to maintain nitrogen balance and tissue repair. Most guidelines recommend 1.2–2.0 g/kg/day, with a increase to 2.0–2.5 g/kg/day for those undergoing CRRT. In contrast, patients with CKD should maintain a protein intake of 0.55–0.8 g/kg/day to mitigate glomerular hyperfiltration and toxin accumulation. Some countries may implement lower protein regimens with ketoacid or essential amino acid supplementation. During dialysis, protein intake should be appropriately increased to 1.0–1.2 g/kg/day due to protein losses. Elderly individuals with CKD, due to increased risk of sarcopenia and energy expenditure, generally recommend a minimum of 0.8 g/kg/day, emphasizing energy adequacy and a balance between protein quality. Overall, the core consensus among China, the United States, Australia, and Europe are that under different disease courses and metabolic states, protein supply should take into account both protecting the kidneys and maintaining body nutrition to achieve individualized and precise management.

3.1.2. Electrolytes

The kidneys are the primary organ regulating electrolytes. Therefore, patients with kidney disease often experience electrolyte imbalances. Potassium, phosphorus, and sodium are the three most impactful electrolytes. Recommended daily intakes for these electrolytes are listed in table 2 below:

Table 2. Recommended daily electrolyte intakes for patients with kidney disease in different countries and regions [7-10].

Country / Guideline	Potassium (K) Intake Recommendation	Sodium (Na) Intake Recommendation	Phosphorus (P) Intake Recommendation
China (2021 Guidelines)	Adjusted according to serum potassium and renal function: generally 2.0–3.0 g/day; <2.0 g/day for AKI or anuric patients; maintain 2–3 g/day for dialysis patients.	<2.0 g/day Na (≈5 g of salt); all CKD and dialysis patients should strictly restrict sodium intake and avoid pickled or processed foods.	<800–1000 mg/day; further restriction if hyperphosphatemia occurs; use phosphate binders as needed.
USA KDOQI / NKF (2020)	No fixed value; guided by serum potassium monitoring. For CKD patients with serum K^+ > 5.0 mmol/L, intake < 2.4 g/day; individualized management for AKI or CRRT.	<2.3 g/day Na (≈6 g of salt); low-sodium diet helps reduce blood pressure and proteinuria.	800–1000 mg/day; emphasize limiting *added phosphates* from processed foods and beverages; phosphate binders recommended when necessary.
Australia KHA-CARI (2019)	Managed dynamically based on serum K^+: CKD 2–3 g/day; during dialysis maintain serum K^+ within 3.5–5.5 mmol/L; avoid high-potassium foods.	<100 mmol/day (≈2.3 g Na); sodium restriction also applies to dialysis patients; adjust according to fluid status.	800–1000 mg/day; prioritize plant-based proteins (lower absorption rate); avoid processed foods.
Europe ESPEN (2021)	No fixed target; emphasize individualized monitoring of serum potassium; in severe AKI/CRRT patients, restriction may be relaxed due to increased clearance.	Consistent recommendation of <2.0 g/day Na; may be lower for critically ill or volume-overloaded patients.	800–1000 mg/day; restrict dietary phosphorus for CKD and dialysis patients; prevent hypophosphatemia during CRRT in severe AKI.

Guidelines from various countries have reached a consensus on electrolyte management: sodium is generally limited to ≤2 g/day, phosphorus is controlled at 800-1000 mg/day, and potassium is adjusted individually based on serum potassium levels. The overall goal is to maintain electrolyte balance while preventing excessive restriction that leads to malnutrition.

3.2. Special Medical Foods for Different Kidney Disease Scenarios

3.2.1. AKI patients

AKI patients are in a state of intense stress and high catabolic metabolism, which leads to increased protein breakdown and reduced synthesis in the body, resulting in a negative nitrogen balance. Therefore, patients need higher protein to meet their nutritional needs. According to recent studies, protein requirements may increase from 1.2~2.0 g·kg-1·day-1 to 2.5 g·kg-1·day-1. However, related studies have shown that increasing protein and energy does not improve renal function. In addition, glutamine is considered to be an amino acid that can help critically ill patients reduce infection and improve their condition. However, recent studies have shown that providing this substance to critically ill patients will increase the patient's mortality rate within 6 months [11]. Therefore, certain types of protein substances should be added and selected with caution.

Due to the rapid decline in the renal filtration function of AKI patients, metabolic acidosis often occurs. Selenium deficiency increases the risk of cardiovascular disease, thereby affecting renal perfusion and leading to chronic kidney disease. Therefore, special medical foods for AKI patients can supplement selenium in appropriate amounts [5].

3.2.2. CKD patients

The metabolic state of CKD patients is prone to chronic protein energy consumption and malnutrition. Nutrition varies for different disease populations, especially the elderly CKD and diabetic CKD patients.

For elderly CKD patients in the mild to mid-stage, like other CKD patients, limiting protein intake can reduce the burden on the kidneys; however, because the elderly are also facing aging problems, the demand for protein increases: aging is characterized by multiple behavioral and physiological changes across organs and systems, which can impair protein utilization and increase its demand. On the one hand, due to the decline in basal metabolism and problems such as insulin and protein anabolism resistance, available nutrients are scarce, and protein synthesis is reduced. On the other hand, protein degradation, increased protein oxidative modification, and the accumulation of inflammatory diseases lead to an increased demand for protein, which in turn requires more protein from the outside world. Current studies have shown that limiting protein intake has a positive effect on adult patients with mild or severe CKD, but for elderly patients, whether it will have adverse effects still needs further research. A study followed up the effect of total protein, plant protein, and animal protein intake on the mortality rate of elderly CKD patients for 10 years. The results showed that there was a significant interaction between total protein intake and CKD. Higher levels of total protein, plant protein, and animal protein intake were associated with a lower risk of all-cause mortality. Especially for patients with mild and moderate CKD, the benefits of protein may outweigh the disadvantages [12,13]. However, it is worth noting that for patients with non-dialysis CKD stages 3-5, multiple national guidelines agree that high protein intake should be avoided and recommend controlling it to around 0.55–0.6 g/(kg·d). Both the Chinese and American guidelines allow a very low protein diet combined with ketoacid preparations. The European and Japanese guidelines pay more attention to the physical function and muscle mass of the elderly and recommend that elderly CDK non-dialysis patients consume approximately 0.8 g/(kg·d) [10,14,15].

The nutritional status of diabetic CKD patients is more complex, and it is necessary to balance the problems of abnormal blood sugar and abnormal kidney metabolic function. At the same time, the gastrointestinal dysfunction caused by diabetes, which leads to loss of appetite, poor digestion and absorption, and ultimately malnutrition, also requires special attention. Therefore, diabetic nephropathy patients will have complex and diverse nutritional problems due to the mutual influence of multiple physical abnormalities and need to intervene in the patient's nutritional status through individualized assessment.

For diabetic CKD patients, low protein intake is recommended to reduce the burden on the kidneys. According to the study on protein intake and progression of renal function damage in diabetic nephropathy patients, for early DKD patients, a low-protein diet has no significant effect on the deterioration of renal function [15].

However, for diabetic nephropathy patients, both China and the United States recommend that in order to control blood sugar, they need to consume more protein than patients with stable metabolism [7-10].

China also recommends that diabetic patients with CKD stages 3-5 need to consume more plant protein, while the United States does not make any recommendations on the type of protein [7.9]. Recommending more plant protein intake may be related to stabilizing the patient's blood sugar. According to a survey on the dietary protein intake of early pregnant women in Beijing, red meat, mainly pork, is a risk factor for gestational diabetes mellitus (GDM), while the frequency of red meat and plant protein intake is not related to GDM. Therefore, for patients who already have diabetes, the protein formula of special medical foods is mainly based on red meat or plant protein.

Since diabetic CKD patients are prone to malnutrition, they often suffer from vitamin deficiency, such as the vitamin D deficiency and study showed vitamin D3 can reduce podocyte damage in the kidneys of stage II diabetic mice, have a protective effect on the kidneys, and thus delay the progression of diabetic nephropathy [16]. Therefore, it is recommended to conduct more in-depth research on the effect of vitamin D3 on podocytes in the future, focusing on whether vitamin D3 has a protective effect on human podocytes, so as to improve and perfect the special medical foods for diabetic CKD patients.

Traditional medicine is also an important focus for studying and solving the nutritional problems of diabetic nephropathy patients. Hibiscus truncatum is a traditional Chinese medicine. The ancient medical book Compendium of Materia Medica from the Ming Dynasty clearly records that it has the effect of "detoxification and swelling reduction". Traditional Chinese medicine has widely used it in the treatment of kidney diseases such as diabetic nephropathy. Recent studies have also shown that flavonoids, the main active ingredients of hibiscus flowers, play a positive role in inhibiting diabetic nephropathy [3]. At the same time, the multi-component and multi-target holistic regulatory characteristics of hibiscus flowers may reduce the adverse reactions and risks of multiple medications in current clinical treatments and deserve further in-depth study. In Turkish folk medicine, horsetail is a widely used drug for the treatment of diabetes and kidney disease. Studies have shown that although the activity of horsetail ethanol extract decreases after digestion, it still has a significant effect in preventing diabetes and kidney damage [4].

4. Functional Foods for Kidney Disease Patients

4.1. Research Progress on the Effects of Functional Foods on Kidney Disease

The primary goal of functional foods is to study the effects of specific ingredients on human mechanisms, thereby promoting health and preventing disease. Therefore, in addition to considering commonly used nutritional factors with established functions and mechanisms of action, functional foods also conduct experimental research on substances with potential related functions. Functional foods carry a greater significance in food and nutrition research and also play a positive and important role for individuals with poor kidney function, those at potential risk of developing kidney disease, or those with a prognosis for kidney disease.

4.2. Cell Apoptosis Caused by Kidney Disease

Abnormal kidney function may be caused by abnormalities in other body structures or by damage to the kidney itself. Especially in chronic kidney disease, as the disease progresses, kidney tissue damage worsens, and the related cell apoptosis problem will become more and more obvious. The cell apoptosis mechanism caused by kidney disease is complex and is affected by factors such as the type of kidney disease.

Taking the mechanism of podocyte apoptosis caused by diabetic nephropathy as an example, podocytes are a type of cell located on the outside of the glomerular capillary basement membrane (GBM) and are one of the key cells that constitute the glomerular filtration barrier. The occurrence and development of diabetic nephropathy are closely related to their number, density, slit diaphragm and cytoskeleton structure. Under pathological conditions, mitochondria in the kidney will have dynamic disorders, autophagy disorders, biosynthesis disorders, etc., causing damage to podocytes and even initiating the podocyte apoptosis mechanism, which reduces the number of podocytes in the kidney and affects the kidney. At the same time, injured podocytes also release chemokines, leading to local inflammation. Podocytes also express receptors for various inflammatory cytokines and are therefore potential targets for the harmful effects of a pro-inflammatory environment. In diabetic patients, an imbalance between oxidation and antioxidant activity results in oxidative stress, which damages podocytes. In addition, complex mechanisms such as lipotoxicity and epigenetics can also damage podocytes [16, 17].

4.3. Inhibitory Effect of Functional Foods on Cell Apoptosis

Currently, one of the research focuses on functional foods for patients with kidney disease is to alleviate the apoptosis of kidney cells or re-stimulate the activity of kidney cells, thereby improving kidney function.

4.3.1. Flavonoids

Flavonoids, also known as bioflavonoids, are a class of polyphenolic compounds that are widely found in the plant kingdom (mainly in leaves, flowers, rhizomes, and fruits of plants). They have multiple biological functions such as antioxidants, tumor inhibition, cardiovascular protection, anti-inflammatory and immune enhancement.

Epigallocatechin-3-gallate (EGCG) is a common compound with good antioxidant, free radical scavenging, anti-cancer, anti-aging, and anti-apoptosis functions. Studies have found that EGCG has an inhibitory effect on cell apoptosis in AKI mice; when rats were gavaged with 20, 40, and 80 mg/kg per day for 28 consecutive days, it was able to reduce the expression of apoptotic and inflammatory proteins in the rat kidneys and increase the expression of anti-apoptotic proteins, thereby reducing cell apoptosis and improving kidney function [17].

4.3.2. Saponin compounds

Saponin compounds are also a class of compounds that are widely found in plants and have biological effects such as immunomodulation, antioxidant, antimicrobial, lipid metabolism regulation and cholesterol reduction. According to research, ginsenoside (Rg1) can reduce intracellular ROS peroxidation damage products, protect cell mitochondria, and reduce renal tubular epithelial cell apoptosis [18]

4.3.3. Vitamins

Vitamin D has a good biological response, with the function of inflammatory response, regulating the body's immunity, and reducing oxidative stress damage. The study by Ming-Chun Hsieh et al. showed that vitamin D intake is closely related to the occurrence and development of AKI. The serum vitamin D levels and active forms of SA-AKI patients are significantly lower than those of normal people, and the vitamin D content is significantly negatively correlated with the severity and mortality of AKI [19].

Vitamin D3 is the most active form of vitamin D in the body. For patients with type 2 diabetes, vitamin D3 may have the effect of reducing podocyte apoptosis]. According to the experiment, after vitamin D3 intervention, the podocyte foot process injury of experimental mice was significantly alleviated under electron microscopy compared with the diabetic model group, and the expression levels of nephrin and podocyte marker protein (Podocalyxin, PCX) in the kidney tissue were significantly increased. The above research results show that vitamin D3 can reverse podocyte injury by upregulating the expression of podocyte nephrin and PCX, reducing urinary albumin excretion, and increasing the clearance rate of serum creatinine, thereby delaying the development of diabetic nephropathy [16].

5. Conclusion

FSMs primarily address the specific needs of patients, analyzing the types and proportions of nutrients. For kidney patients, protein and inorganic salts are primarily considered. Currently, for patients with a high prevalence of CKD, such as those in early-stage CKD and those not undergoing dialysis, who present at a relatively mild stage and with relatively simple pathology, there is a relatively broad consensus on key nutrient and energy requirements, and relatively mature products are in clinical use. However, for patients with more specific medical conditions or complex pathologies, such as the elderly, pregnant women, and diabetics, a high degree of consensus on key nutrient requirements is often less established, making it difficult to formulate FSMs. This has led to deficiencies and confusion in the clinical and R&D of FSMs for these patients. Therefore, greater government and academic investment is needed to further address the nutritional needs of these patients.

Functional foods primary focus shifts from basic nutrients to active substances that provide health benefits such as flavonoids and saponins and explains the mechanisms and effects in treating kidney disease, as well as the role of vitamins in improving the hair growth of patients with kidney disease. It also analyzes and summarizes functional foods for patients with kidney disease. and their mechanisms of action and toxicity are not fully understood.

In the future, research should focus on the core issues facing patients with kidney disease, based on high-quality and large-scale clinical evidence-based research.

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