Review

Dietary fiber and gut microbiota in renal diets

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Abstract: Nutrition is crucial for the management of patients affected by chronic kidney disease to slow down disease progression and to correct symptoms. The mainstay of nutritional approach to renal patients is protein restriction coupled with adequate energy supply to prevent malnutrition. However, other aspects of renal diets, including fiber content, can be beneficial. This paper summarizes the latest literature on the relationship between the type of dietary fiber and prevention and management of CKD, with special attention to intestinal microbiota and the potential protective role of renal diets. A proper amount of fiber should be recommended not only in general population but also in chronic kidney disease patients, to asses an adequate composition and metabolism of intestinal microbiota and to reduce the risks connected with obesity, diabetes and dyslipidemia.

Keywords: renal diets; fiber; renal nutrition; chronic kidney disease; gut microbiota

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1. Introduction

Chronic kidney disease (CKD) is a growing public health problem, affecting about 10% of the population worldwide, with diabetes, hypertension and obesity being the most important risk factors for its occurrence in developed countries [1] The importance of nutrition in a nephrology setting has been recognized as crucial for the management of CKD to slow down disease progression and to correct symptoms. The mainstay of dietary treatment of renal patients has been protein restriction coupled with adequate energy supply to prevent malnutrition and with correct management of electrolytes abnormalities [2]. In addition, renal diet composition may also influence intestinal microbiota, which has been proved to play a role in reducing toxins production and preserve renal function, slowing CKD progression. Several aspects of renal diets, including fiber content, can modulate the intestinal microbiota metabolism of CKD patients [3].

The purpose of this paper is to summarize the latest literature on the relationship between the type of fiber and prevention and management of CKD, with special attention to intestinal microbiota and the potential protective role of renal diets.

2. Fiber definition and recommendation

The research about the use of dietary fiber and human health is large and heterogeneous. Since the 70's in Western countries recommendations of scientific societies [4-9] have suggested an adequate intake of fiber for a healthy diet (Table 1).

In the general population, the current guidelines recommend a total fiber (both soluble and insoluble) intake of 20–35 g/day. The mean intake of dietary fiber in the United States is 17 g/day with only 5% of the population meeting the adequate intake [10].

Table 1. Guidelines recommendations on fiber intake

- ADA (2014): 14g/1000 kcal or 25 g/day women, 38 g/day men [4]
- AHA (2014): Rich in fiber [5]
- USA Guideline (2015): 14 g/1000kcal [6]
- EFSA European Guideline (2010): 25 g/day [7]
- KDOQI (2007) [8] / KDIGO (2015) [9]: no specific recommendation

Legend: ADA = American Dietetic Association; AHA = American Heart Association; EFSA= European Food Safety Autority; KDOQI = Kidney Disease Outcomes Quality Initiative; KDIGO = Kidney Disease Improving Global Outcomes

Regulatory Authorities recommend a proper intake to assess benefits on stool excretion for laxation and intestinal regularity, and for metabolic action in maintaining proper cholesterol and glucose metabolism. The role of fiber in health and disease is more complex and the modern analytic techniques open the way to the complex interaction on human metabolism connected with the fiber intake. Beyond the total quantity of fiber to be consumed, little has been done to specify the types of fiber or the proportions of the different fiber-containing food to reach an optimal intake.

An appropriate definition of dietary fiber is essential [11]. In 2007 FAO/WHO experts recommended the introduction of the concept that the term "dietary fiber" is referred to nondigestible carbohydrates contained in grains, seeds, vegetable and fruits [12]. This is the most internationally accepted definition, including the European Union. Canada and USA are still undecided with proposals.

Dietary fiber is made up of carbohydrates polymers with three or more monomeric units (MU), plus "associated substances". Table 2 presents the classification of dietary fiber according to chemical structure. Other physiochemical characteristics like water solubility, viscosity and fermentability, have been considered.

Table 2. Classification of dietary fiber according to main chemical components, main food source.

Subgroup	Class of poly, oligosaccharides	Main sources	Water solubility	Viscosity	Fermentability
No Starch Polysaccharides MU ≥ 10	Cellulose, hemicellulose.	Outer layers of cereals, starchy endosperm fruits and vegetable cell walls, psyllium.	++/+	Varies with source	++/+ Water soluble are rapidly fermented
	Mannans, heteromannans.	Grain legumes, guar gum.	++/+++	-/+++	+ /++
	Pectins	Fruit peel, beetroot, rice endosperm, legumes.	++	++	++
	Inulin and fructans	Chicory root, Jerusalem artichoke, onion, cereal grains.	++	-	++
Resistant Oligosaccharides	α-galactosides β fructo-oligosaccharides (FOS)	Polymers derived by hydrolysis from polysaccharides.	+++	-	+++

MU 3-9	α-galacto- oligosaccharides (GOS) β-galacto- oligosaccharides (TOS) xylo- oligosaccharides (XOS) arabino-xylo-oligosaccharides (AXOS) resistant destri, polydextrose				
Resistant Starch MU ≥ 10	Type 1-physically inaccessible starch Type 2-granular starches Type 3-gelatinised and retrograded starch Type 4-chemically modified	Tp1-whole grains and legumes Tp 2-Green banana Tp 3-Colled starches Tp4-syntetized	-	-	++/+
Associated substances	Lignin, waxes, chitins	cell walls of plants, red algae, fungi.	-	- waxes ++	-

In the European Union (EU) the minimum number of carbohydrates is 3 (MU≥3). To be included in the fiber definition a healthy benefit is required, such as "decrease of intestinal transit time, increase of stool bulk", "reduction in blood cholesterol" and "modulation of glucose metabolism" [13]

The European Food Safety Authority (EFSA) opinions, on health claims related to dietary fiber, report the use of the term "soluble" and "insoluble" in the literature to classify dietary fiber according to a physicochemical characteristic linked to different physiological effects [14]. However, aqueous solubility does not always predict physiological effects, so it has been proposed a different classification according to main characteristic of viscosity, fermentability and bulking effect in the colon [15]. There is an overlap between the characteristic used for classification and that create confusion in correlating certain dietary fiber characteristics to observed health outcomes (Table 3)

Table 3. Main fibers physicochemical characheristic.

	Water Solubility		Viscosity		Fermentability	
	YES	NO	YES	NO	YES	NO
Beta-glucan, Gums, Pectins, Mucilage						
Cellulose lignans						
Fructo-oligosaccharides Galacto-oligosaccharides						
Inulin						
Psyllium						
Resistant starch						

Solubility refers to dissolution in water, but it is the viscosity (capacity to gel with water) of certain soluble fibers that influences chyme consistency and slows digestion, by digestive enzymes, of consumed nutrients to absorbable components. Oligosaccharides are highly soluble and fermentable fibers and include fructo-oligosaccharides (FOS) and galacto-oligosaccharides (GOS). These short chain fibers are highly fermentable due to their small size and solubility.

Soluble, non-viscous, readily fermentable fibers (inulin, wheat dextrin) dissolve in water and are rapidly and completely fermented. Soluble, viscous, readily fermentable fibers (β-glucan, gums, pectin) are similar but form a gel-like consistency with water. These characteristics are then lost following fermentation. Soluble, viscous, slowly fermented fibers (psyllium) also form a gel-like consistency, but do not undergo extensive fermentation. As such, the capacity to interact with water is preserved throughout the colon. This allows softening of stools in those suffering from constipation and adds form to loose stools. Insoluble fibers (wheat bran, lignin, cellulose) exert a laxative effect by stimulation and irritation of gut mucosa to increase secretion and peristalsis [16].

EFSA included in the definition of dietary fiber also polymers obtained by physical, enzymatic or chemical means with a demonstrated beneficial physiological effects [14].

The EU Regulation (EC) No 1924/2006 on nutrition and health claims for foods specifies the requirement for the use of the terms “source of fiber” or “high in fiber”.

‘Source of fiber’ is a claim that a food is a source of fiber, and any claim likely to have the same meaning for the consumer, may only be made where the product contains at least 3 g of fiber per 100 g or at least 1·5 g of fiber per 100 kcal (418 kJ).

“High fiber” reflects the claim that a food is high in fiber, and any claim likely to have the same meaning for the consumer, may only be made where the product contains at least 6 g of fiber per 100 g or at least 3 g of fiber per 100 kcal (418 kJ) [17].

3. Dietary fiber and chronic kidney disease.

The study of fiber and other dietary components is complex, not only for different proprieties of different kind of fibers. First, it is difficult to assess the dietary fiber intake, no biomarker available and dietary histories are often unreliable. Then the interaction with human gastrointestinal tract con be different due to the previous dietary fiber habits, gut microbiota differences in various populations and previous disease or medication [18]. Fiber intake have been investigated as a dietary aspect that may exert a healthy action on renal health trough different way (figure 1).

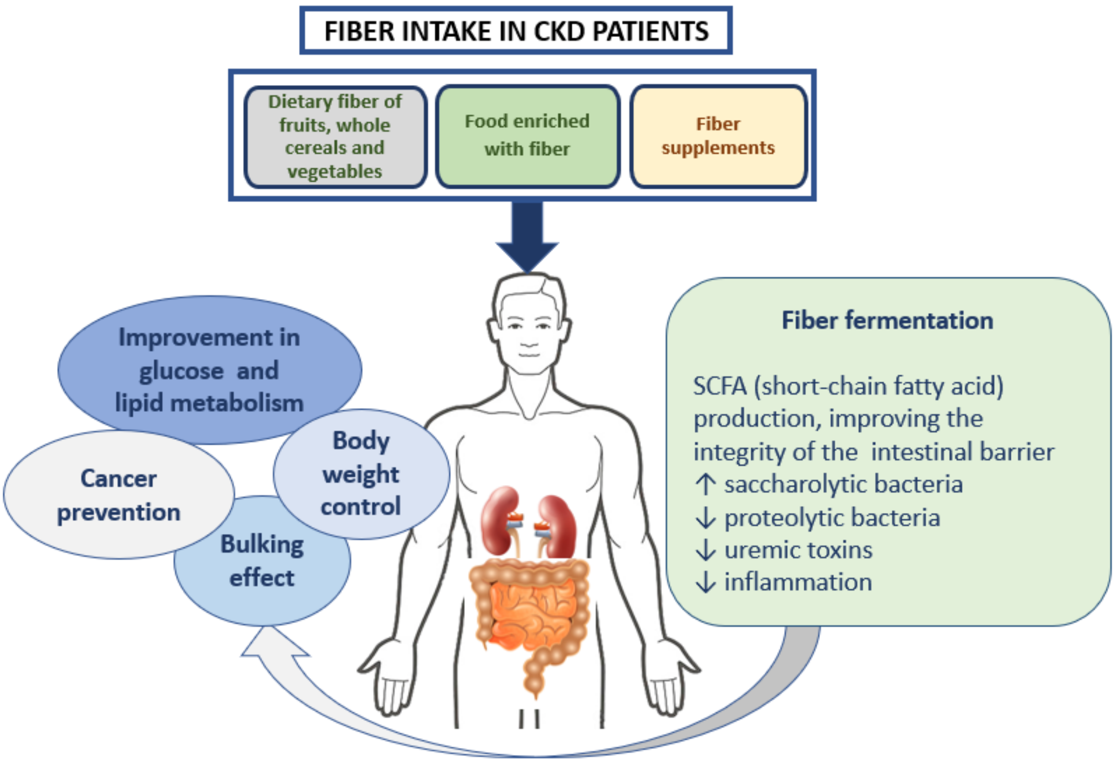

Figure 1. Potential beneficial effects of fiber in renal health. Fiber intake and fermentation are of crucial importance in the kidney-intestine axis, both for kidney health and for outcomes associated with other relevant conditions, such as cancer, diabetes, obesity.

3.1. Role in intestinal transit.

The bulking effect is important to maintain a proper intestinal transit. In Europe, constipation is one of the most common gastrointestinal complaints; the causes are variable including medication effects, increasing age, lifestyle and dietary habits. These effects are mediated by the water-binding capacity of dietary fiber and by fermentation, which alters osmotic balance and increases fecal biomass. Fiber from wheat bran has been shown to have a high bulking effect (5.4 g stool weight increase per 1 g of wheat fiber) due to its resistance to fermentation [10]. In a cohort study conducted in 3 million US Veterans a severe constipation status was correlated with an increased risk of CKD and a faster decline of glomerular filtration rate (eGFR) [19] In CKD, medications like phosphate binders or antibiotics, water reduction and dietary restriction due to potassium management exacerbate constipation.

3.2. Role in weight control.

Same viscous types of fiber (such as guar gum, pectins) were associated with reduced appetite and a better control of body weight. A diet rich in fiber is characterized by the presence of whole cereals, legumes, fruits and vegetables, all foods with a low-density caloric amount.

Observational evidence for the effects of different sources or types of dietary fiber on body weight management is rather limited and inconsistent in terms of strength of association. There is some evidence from pooled data from five EPIC centers study that individuals with higher total and grain fiber intakes experienced smaller annual weight gains. Over the 6·5-years follow-up, for each 10 g greater intake of total fiber, weight gain was less by 39 g/year in the 89 000+ European participants. This apparently small annual improvement may potentially contribute to significantly greater lifetime weight stability in higher fiber consumers [20]. Obesity is an important risk factor for CKD, a healthy body weight throughout the life, as a result of education to a proper diet and lifestyle is a public health goal and should be recommended not only to prevent kidney disease [21].

A reduced appetite can be a harmful effect when symptoms of uremia as loss of appetite or nausea can negatively affect the nutritional status of patients at the end stage of renal disease (ESRD). Salmean et al. [22] conducted a pilot study to test the impact on appetite on adults with CKD of a diet with foods added in fiber. Participants were provided with control foods (cookies, snack bars and breakfast cereal) containing < 2 g/day of fiber for 2 weeks, followed by similar foods providing 23 g/day (pea hull, inulin and resistant corn dextrin) for 4 weeks, to incorporate into their usual diets. No change in body weight or energy intake occurred over the six-week study. Scores for appetite did not change, but suggested poor appetite in 7 participants, with or without added fiber, and a significant risk of at least 5% weight loss within six months. Low food intake is an important risk factor for malnutrition and adverse outcomes in patients with CKD. Poor appetite is common with progression of renal damage and the impact of a diet rich in fiber on appetite, with or without supplements, justifies further investigation at different stage of CKD [22].

3.3. Role in cancer prevention.

kidney cancer is among the 10th most common presenting cancers in the Western world, with suspected lifestyle and dietary etiology. A recent review by Huang et al. summarized the evidence from two cohort and five case–control studies in a meta-analysis on dietary fiber intake and risk of renal cell carcinoma. When comparing the highest against the lowest dietary fiber consumers, the pooled estimate of risk for renal cell carcinoma indicated that the total dietary fiber intake was associated with reduced RCC risk (RR 0.84). The study also revealed some differential associations according to the source of dietary fiber (greatest risk reductions for fiber from legume and vegetable sources, rather than fiber from grains or fruit). However, using a dose–response meta-analysis approach, the authors were unable to report any evidence of diminishing risk with increasing intakes of dietary fiber. This points to the need for further, large prospective cohort studies to explore potential links between dietary habits and kidney cancer [23]. The World Cancer Research Fund (WCRF) analysis of evidence on cancer prevention and survival recommended a diet rich in whole grain cereals, fruits and vegetable [24].

3.4. Role in glucose and lipid metabolism.

Diabetes is a growing worldwide epidemic and the CKD is the most expensive and debilitating complications. Cardiovascular disease (CVD) is a frequent cause of mortality in patients with DM and CKD is a risk for CVD [8,9].

There is sufficient evidence to support a number of EFSA health claims that certain types of fiber, including β-glucans and pectins (viscous, soluble and fermentable), if consumed within a meal, may contribute to the reduction of blood glucose rise after a meal. Psyllium (viscous, soluble but not fermentable) delay degradation and absorption of nutrients, can reduce total glucose and cholesterol absorption [15,25].

The cholesterol-lowering effect depends on increased viscosity of fiber that reduces the re-absorption of bile acids, increases the synthesis of bile acids from cholesterol, and reduces circulating (LDL) cholesterol concentrations [16].

Evidence support a reduce risk for type 2 diabetes, with additional fiber daily consumption; both soluble and insoluble fibers were associated. The American Diabetes Association (ADA) recommends that patients with DM should consume at least 14 grams of fiber for each 1000 kcals daily and it suggests that carbohydrate intake from vegetables, fruits, legumes, and whole grains, with an emphasis on foods higher in fiber and lower in glycemic load, is preferred over other sources of sugar [4]. The American Heart Association (AHA) also endorses healthy dietary patterns rich in fiber to prevent CVD, such as Dietary Approaches to Stop Hypertension (DASH) and Mediterranean diets [5].

A recent review analyzed the role of dietary fiber in diabetic kidney disease. The Authors starting from 1814 studies, evaluated 48 articles and due to lack of dietary or renal outcome information, included only 7 clinical trials. Moreover, only two of them provide information about the kinds of fiber used, soluble or insoluble. Limitation for the small numbers of studies, for short term follow-up time, for the time and the amount of fiber (in most studies included fiber intake was lower than recommend by most guidelines) led to the conclusion that further investigation is needed to deliver evidence that is currently still limited [26].

3.5. Role in gut microbiome.

Dietary fiber is the key substrate for microbial growth of bacteria living in the gut (prebiotic action). The gut microbiota is a true ecosystem made up by more than 10^{14} microorganisms living throughout the intestinal tract. The cell number of this internal organism is 100 times greater than the total cell number of the human body and the gene content of the total DNA of this bacterial mass is greater than 4 million genes, whereas our genome is only composed by 23 000 genes. The colonization is established in the first years of life, reaching the maximum complexity in the adulthood, when the dominant species are Bacteroides, Firmicutes and Actinobacteria [27].

Fermentable fibers, such as oligosaccharides, β-glucans, gums, some hemicelluloses, and some resistant starches are the substrate for bacteria metabolism producing short chain fatty acids (SCFAs), primarily acetate, propionate, and butyrate. Recent evidence has supported the role of these metabolites in regulation of immunity, blood pressure, glucose and lipid metabolism, and seems to be the link between microbiota and host homeostasis. SCFAs are absorbed, more than 90 % by colonic epithelial cells, providing an important energy source. Due to fermentation fiber provide an energy intake of 2 kcal per gram [15]. Butyrate is rapidly used as energy source by colonocyte; most of acetate and propionate enters the portal circulation and peripheral blood. SCFAs reach the bloodstream and act on the immune system by modulating inflammatory gene expression, chemotaxis, differentiation, proliferation and apoptosis. These beneficial effects are related to their property as histone acetylation inhibitors and activation of transmembrane cognate G protein coupled receptors (GPCRs). An important role is the trophic action on intestinal epithelial cells, a physical barrier against the entrance of pathogenic microorganisms or their molecules into the portal circulation. Changes in the intestinal barrier with an increased permeability are common in CKD. SCFAs may contribute to kidney health by reducing stimuli to systemic inflammation, maintaining an intact mucosal barrier, both modulating the immune system and the anti-inflammatory response [28].

Data from 14,543 participants in the National Health and Nutrition Examination Survey III (NHANES III) showed for each 10-g/day increase in total fiber intake (total, soluble, and insoluble), the odds of elevated serum C-reactive protein levels were decreased by 11% and 38% in those without and with kidney disease, respectively. The authors concluded that taken together these data suggest a stronger role of dietary fiber in lowering inflammation in the CKD population and this is a likely potential mechanism for the association of higher dietary fiber with lower mortality. Unfortunately, according to NANES III data, the average dietary fiber intake in the CKD population is about 15,4 g/day, which is much lower than recommended [29].

3.6. Role in biomarkers of renal function.

A dysbiosis of the microbiota seems to be a risk susceptibility factor for the development of kidney disease, following injury or in predisposed individuals. The progressive reduction in kidney function significantly contributes to worsen the intestinal dysbiosis [30, 31]. More research is needed to evaluate the gut microbiota profile in CKD patients. Therefore, the imbalance in gut microbiota contributes to the accumulation of gut-derived uremic toxins. Toxic gases, indoxyl sulphate, p-Cresyl sulphate, amines, ammonia and trimethylamine n-oxide (TMAO) as well as precursors for lipopolysaccharides (LPS) may be absorbed into the bloodstream and be responsible for systemic inflammation. Indeed, several studies have shown that these toxins are reliable markers of cardiovascular disease and mortality in CKD patient [27,32]. The increase in bowel transit velocity, the reduction of constipation and proliferation of intestinal bacteria may reduce serum urea by altering the urea enterohepatic cycling, increasing nitrogen excretion via fecal mass [33]. Urea has been demonstrated to be permeable trough the colon. Similarly, creatinine is transportable across the intestinal epithelium and has been proposed to be metabolized by intestinal bacteria, reducing metabolite retention in CKD. Data about dietary fiber effects in CKD using serum creatinine and urea have been reviewed by Chiavaroli et al [34]. The systematic review and metanalysis from 8051 report identified, included only 14 controlled feeding trials that met the eligibility criteria for analyses, involving 143 participants with median age of 51.9 years. No data have been reported about the stage of CKD, degree of renal impairment, fiber intake at baseline. The strengths of the analysis is the median fiber dose supplemented, about 27 g/ day, which is consistent with the recommendation for adults. A reduction in urea and creatinine as biomarker of renal function was correlated with dietary fiber, in a dose-dependent manner for serum creatinine level. In most studies, fiber was supplemented as fermentable fiber type (psyllium, gum Arabic, inulin and lactulose), medium dose 26,9 but a very high range of 3,1-50 g/day. The incidence of CKD assessing e-GFR has been evaluated by the Tehran Lipid and Glucose Study that followed 1630 participants, mean age 42.8 years, for 6 years, who were initially free from CKD. Data about dietary fiber has been collected with a valid and reliable food frequency questionnaire. The authors observed a reduced risk of incident CKD in higher tertiles of fiber intake (average 36.6 g/day). The study reported the distribution of fiber from different foods (fruits, vegetables, cereals and legumes). Every 5 g /day increase in total fiber, the risk of incident CKD decreased by 11%; a protective association were observed for vegetables and legumes fiber [35].

4. Renal diets.

The diets for CKD patients are characterized by the control or reduction of protein intake, the increase of carbohydrates supply and the increase of plant- origin protein and food in respect to animal-origin foods. In other words, in respect to current western diet pattern, diets implemented in renal patients consists in an unbalance in favor to complex carbohydrate and fibers in respect to animal-origin proteins and refined foods [36].

All these aspects may have several favorable effects on intestinal microbiota metabolism. One of the effects of a successful dietary restriction is the lowering of nitrogen waste products retention, the most common biomarker being urea. In CKD, the accumulation of urea in body fluids causes its diffusion into the intestinal lumen, where it is converted into ammonia by the urease-positive species, and finally hydrolyzed to ammonium hydroxide. The latter causes changes of the tight junctions, damage to the epithelial barrier and increase in intestinal permeability, resulting in the passage into blood stream circulation of bacterial toxins. It follows the activation of a local and systemic chronic inflammatory mechanism that induces further damage to the intestinal epithelial barrier, triggering a vicious circle that also favors the progression of renal damage [37] Through saccharolytic fermentation in the intestinal lumen, carbohydrates are converted to short chain fatty acids (Short Chain Fatty Acids, SCFA), such as acetate, butyrate and propionate, which have anti-inflammatory and protective effects on immune function and intestinal barrier integrity. Instead the products of proteolytic fermentation, such as phenols, indole, amines and ammonium, are potentially toxic metabolites and reduce the circulating levels of SCFA. Complex carbohydrates such as dietary fiber and fructo-oligosaccharides (FOS), obtained by hydrolysis of plant-origin inulin, are today recognized as "prebiotics", that is substances able of favorably modifying the composition of intestinal microbiota, stimulating growth and metabolic activity of beneficial microorganisms, such as Bifido-bacteria and Lactobacilli with saccharolytic metabolism [38,39]. Recent data show that serum concentrations of PCS and IS are reduced by oral p-inulin intake in CKD patients on hemodialysis [40].

Therefore, the diet may have a potential impact in restoring the composition of the microbiota and optimizing homeostasis in patients on CKD. The low-protein renal diets still remain crucial in the therapy of patients with CKD [41]. Diets with a very low protein and vegan content reduce the intake of substrates for protein fermentation and ensure a high intake of dietary fiber, which increases the transit speed in the colon, decreasing the production and absorption of uremic toxins [42]. Patients with CKD not yet on dialysis switched from a modest diet protein restriction to a high protein restriction (0.3 g / kg body weight / day) with supplementation of essential amino acids and keto-analogs (KA) showed a reduction of 37% in the blood concentration of IS, achieving at the same time an adequate protein metabolism and a low production of urea [43].

Dietary interventions, consisting in the increase of carbohydrates and fibers intake while reducing animal origin protein and refined foods, are potentially useful both in prevention and in the initial phases of CKD. This is the case of the Mediterranean diet or the DASH (Dietary Approaches to Stop

Hypertension), characterized by a high intake of food of vegetable origin rich in natural and fiber prebiotics and a reduced salt intake, refined sugars, animal fats and red meats [44].

Furthermore, it is useful to limit the consumption of processed food products, both because modern conservation processes, which have the purpose of eliminating pathogenic bacteria and guarantee the durability of food, reduce the intake of even commensal micro-organisms beneficial for intestinal flora, and because these products can constitute "hidden" sources of phosphates and sodium. Instead in most advanced stages of CKD, low protein diets, rich in carbohydrates, and sometimes vegetarian are useful options. Finally, it is known that physical activity is associated with benefits on blood pressure control, glucose and lipid metabolism, and endothelial function. A sedentary lifestyle slows intestinal transit and preliminary evidence suggests that exercise is associated with greater changes of intestinal microbiota and a reduction in pathogenic components. In the patient with CKD, exercise is an anabolic stimulus that integrates nutritional interventions to counteract the loss of lean mass, positively influencing nutritional status and quality of life. Therefore, in the management of CKD patients at any stage, regular physical activity should be promoted as an integral part of the nutritional-nutritional plan [45].

5. Fiber in renal diets.

The analysis of nutrients content of four different types of diets for renal patients, shows an average amount of 7.66 g/1000 Kcal for conventional Low Protein Diet (0,6 g protein/kg), 16 g/1000 Kcal of low-protein Vegan diet (0,6 g protein/kg), 11.6 g/1000 Kcal for very low protein diet (VLPD), and 10.4 g/1000 Kcal for a 0,8 g protein/kg diet [46].

In Italy, an animal-based low protein diet includes the use of special low protein foods, formulated to give high number of calories with negligible content of nitrogen, potassium and phosphorous. They are starch-made substitute of regular breads, pasta and bakery products, supported by national health system, with a formulation high in technological value that allow a similar taste to traditional products [47,41].

Fibers were already present in special protein-free foods, baked products in particular, in order to mimic the structural role of gluten. The most used fibers were carob, xanthan gum, guar cellulose and its derivatives [48,49]. Protein-free pasta had a low content of fiber because a specific rout of production was used for its production that didn't need the addition of specific ingredients.

Currently, protein-free products have been further enriched with fibers. Fibers content have been increased significantly in all products, including pasta and baked products, not only for technological reason but also for the well know "metabolic" role of fibers, in particular regarding gut microbiota composition and metabolism.

Comparing the nutritional facts labels of protein-free products available about 10 years ago and the current ones, relevant increase of fibers content clearly emerges. The average content of fiber in bread increased from 4.2 to 10.8 g per 100 g, from 1.5 to 4.8 g per 100 g in pasta and from 0.8 to 3.3 g per 100 g in biscuits and cakes. Instead, fiber content in protein-free flower is quite the same.

Table 4 reports the fiber content of the main categories of protein-free products; the data resulted from the 5 most known brands of protein-free products. Interestingly, fiber content in protein-free products is higher than that of regular products. For example, the average content of fiber for regular pasta is 2.7 g/100 g versus 4.8 g/100 g of protein-free pasta. The average content of fiber in regular bread is 2.7 g/100 g versus 10.8 g/100 g of protein free bread that is even higher than that of whole grain bread, 6.5 g/100 g (fiber content of regular products comes from the National Institute for Food and Nutrition database) [50]. It is quite interesting to observe also that the types of fiber currently used seem more "natural" in respect to the past (Table 4).

Table 4. Fiber content of the main categories of protein-free foods made by 5 most known brands of protein-free products. The data refer to 100 g of edible product.

	Fiber content (g/100 g)		Type of fibers
	Median (IQ)	Min - max	

Bread	12.5 (7.5 - 13)	5.0 - 13	Cellulose, psyllium, apple extract, deglutinated wheat fiber
Bread substitutes	7.4 (6.7 - 9.0)	4.0 - 15	
Pasta	4.8 (2.8 - 5.7)	3.0 - 7.3	Cellulose, inulin
Biscuits and cakes	3.2 (2.0 - 3.6)	0.5 - 8.5	Bamboo fiber, pectin,
Flower (for bread)	3.0 (2.8 - 4.0)	2.7 - 5.4	Cellulose, psyllium, apple extract, deglutinated wheat fiber

Achieving higher fiber intakes remains a concern in the renal diet because of increased potassium and phosphorus levels. Foods added in fiber or supplements may be a useful option for the high energetic amount and for the reduced content in electrolytes.

The question if dietary fiber *per se* or the other nutrients that are present in the foods that are high in fiber decrease systemic inflammation is still open. Fruits and vegetables intake vitamins and antioxidant, that make these foods necessary for a healthy diet, and natural sources are to be preferred [51]. Bioavailability of potassium and phosphorus in fruits, vegetables and whole grains is lower when compared to processed food [52].To reach sufficient amount of dietary fiber and to ensure a low potassium content in diet for patients with advanced CKD, vegetable should be cooked by boiling in water before ingestion and the fruit should be properly selected. [36,53].

Afterall restoration of fiber after a prolonged period of dietary deficiency represents a significant challenge, not simply educational but also physiological. "Addition of" or "change in" fiber intake leads to bloating, abdominal cramps and increased flatulence. Furthermore, delayed gastric emptying and digestion, from soluble and viscous fibers, may aggravate symptoms of dyspepsia. These unwanted symptoms are associated with many gastrointestinal and functional disorders and may affect adherence to adopt a high fiber diet [16].

6. Conclusions

A proper amount of fiber should be recommended not only in the general population but also in people affected by chronic kidney disease, to asses an adequate composition and metabolism of intestinal microbiota and to reduce the risks connected with obesity, diabetes and dyslipidemia.

More clinical studies need to be conducted to assess the potential multifactorial benefits of a natural diet rich in fiber in CKD and define the impact of quality and quantity composition in different kinds of fiber.

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