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Diet, microbiota and health

The impact of diet on health is no longer questioned and a diverse diet is key in this context. A challenge is to understand the main mechanisms that are involved in the links between dietary profiles and chronic diseases. Amongst players is the gut microbiota, which metabolize a myriad of food molecules. While different food items influence the composition and diversity of the gut microbiota, this latter also influences the metabolism of nutrients used by the host. This issue of "The Global Fruit & Veg Newsletter" is focusing on food diversity, food compounds, and human health via the potential contribution of the gut microbiota. Using dietary quality index, Laitinen *et al.* showed in pregnant women that high dietary quality index associates with improved microbiota diversity and increased bacterial species, being beneficial in some chronic disorders. The consumption of fruit and vegetables (F&V) is an integral part of dietary diversity and Lecerf has highlighted recent data regarding the important link between F&V and changes in gut microbiota with potential favorable effects on health. Amongst F&V related molecules, flavonoids are a subclass of polyphenols metabolized by the gut microbiota. Bolling *et al.* summarizes mechanisms of action of flavonoids involving gut inflammatory pathways. These reports highlight the urgent need to understand how food derived molecules are metabolized by the microbiota functional machinery and impact our metabolism.

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Overall Diet Quality Relates to Gut Microbiota Diversity and Abundance

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Dietary recommendations have been compiled for decades to give advice to populations on how to eat to advance health and to lower the risk for many lifestyle related chronic diseases. Generally, a good diet quality is promoted, this including high intakes of fruit and vegetables, high-fiber whole grain products, fish, the selection of low-fat dairy and meats, and low-sugar foods. Recently more attention has been paid to the role of gut microbiota that may act as a mediator for some of the dietary benefits on health. It was shown in our recent study that high diet quality is likely to advance the health-promoting gut microbiota[1].

Diet composition modifies gut microbiota

Many foods, food groups and even nutrients have been linked with gut microbiota composition[2]. The intake of dietary fiber has been the most studied, but ultimately, we eat a combination of foods and nutrients and thus, it is important to consider how an overall diet influences gut microbiota. Clear differences in microbiota have been demonstrated in studies in groups of individuals consuming different dietary patterns including vegetarian or omnivore diets or African and Western diets. Also, a good adherence to a Mediterranean diet has been associated with a beneficial composition of the gut microbiota[3-5].

Overall diet quality relates to gut microbiota

We studied the relation between overall dietary quality and gut microbiota diversity and composition in overweight and obese women[1] as they are at risk for metabolic complications and thus might benefit of dietary and gut microbiota modification. A high gut microbiota diversity has been generally considered as beneficial for health, whilst the lowered diversity has been related to metabolic aberrations like dyslipidemia[6].

In our study, microbiota composition was analyzed from faecal samples of 84 women at early pregnancy using 16SrRNA gene sequencing, and diversity indices were subsequently calculated. Diet quality was measured by a validated diet quality index, which is a short, stand-alone questionnaire for recording consumption of foods (e.g. whole grains, fruit and vegetables, milk products, sweets) during the preceding week and reflects adherence to dietary recommendations[7].

In the study, we reported that women who had the highest diet quality index scores also had higher gut microbiota diversity compared to women with low diet quality scores. Of the index components, particularly whole grains and vegetables were best related to gut microbiota diversity. Further, consumption of whole grains and vegetables on a daily basis was required to yield benefit in the microbiota diversity. When considering microbiota abundances, the genus *Coprococcus, F. prausnitzii* and an unknown species in family *Barnciellaceae* were related to a higher diet quality. An unknown species of genus *Sutterella* was related to lower diet quality.

Our study, alongside with previous evidence, indicate that high diet quality and an overall healthy dietary pattern relates to gut microbiota composition that is generally considered beneficial for health (Figure 1). Thus, modulation of gut microbiota by diet may offer opportunities for advancing health.

High overall dietary quality — High gut microbiota diversity

Figure 1. Overall diet quality relates to gut microbiota

Based on: Laitinen K, Mokkala K. Overall Dietary Quality Relates to Gut Microbiota Diversity and Abundance. Int. J. Mol. Sci. 2019, 20, 1835.

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Fruit and vegetables as modulators of the microbiota

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The microbiota's importance to human health is becoming increasingly apparent. It contributes to the body's immune defences through numerous mechanisms, but also plays a role in the intestinal barrier. It modulates most enterohormones, acts on metabolism, and plays a role in regulating dietary behaviour. Through its connections with the nervous system and its involvement in the production of neurotransmitters, it is also implicated in neurological disorders. Its role in obesity and diabetes is becoming increasingly clear through its effect on adipocyte proliferation, but also on the inflammatory component of these diseases via bacterial lipopolysaccharide (LPS). The microbiota is also implicated in the increased incidence of allergic conditions, colorectal cancer, chronic inflammatory bowel disease, etc. Its quality depends on its composition and diversity.

The purpose of this extensive literature review was to take stock of the role of "whole" plant-based foods – in particular fruit and vegetables (F&V) – on the gut microbiota.

F&V and the gut microbiota

The authors begin by reporting the effects of microbiota-accessible carbohydrates (fermentable or prebiotic carbohydrates) and F&V on the microbiota. The two main markers of a good microbiota (a low ratio of Firmicutes to Bacteroidetes and alpha diversity) are considered to be favourably influenced by these nutrients and foods. However, there are considerable inter-individual variations in their effects

Next, the authors analyse the specific effects on the microbiota of fermentable carbohydrates such as inulin, fructooligosaccharides, xylooligosaccharides and galactooligosaccharides, as well as soluble fibres such as pectin. These modify the production of short-chain fatty acids, which have beneficial metabolic effects. According to more recent findings, the specific role of polyphenols appears to be essential. The microbiota is initially responsible for the biotransformation of polyphenols into a large number of metabolites, resulting in a specific metabolome that is analysed by metabolomics. This biotransformation is mediated by multiple enzymes of bacterial origin. Their specificity depends on the bacterial strains, making investigations into their origin even more complex. The other side of the polyphenol-microbiota interaction concerns the role of polyphenols on the microbiota. These can modulate its composition by inhibiting pathogenic strains and/or promoting the development of "beneficial" bacteria. Their metabolites may also act on the microbiota. This probably contributes to the anti-infectious role of the foods that provide them, although the evidence and clinical reality are still incomplete.

There is a body of data that strongly advocates the importance of consuming whole foods rather than fractions or isolated compounds, because of the interactions between them. This reflects the matrix effect. Food supplements and assembled (ultra-processed) foods do not have the same effects as F&V and cereals consumed whole and in their natural state.

The microbiota and obesity

Lastly, the authors review the role of these foods and their effects on the microbiota and on a number of diseases, mainly obesity. Numerous studies using animal models of obesity have thus shown the effect of consuming various fruits (melon, avocado, bilberry, grape, mango) and vegetables (mushrooms, broccoli, beans, tomatoes, spinach, etc.) on the microbiota and on a number of markers of insulin resistance and systemic inflammation associated with obesity and changes in the microbiota. As an example, there is a description of the effects of diet on *Akkermansia muciniphila,* which is involved in mucus constitution and the microbiota's barrier effect, with a specific role for F&V. Secondly, the effects of the microbiota on inflammation of the colon are also detailed in animal models. For example, anthocyanins, one of the families of polyphenols, have significant anti-inflammatory effects, reducing inflammation induced by LPS and several inflammatory cytokines. However, the full range of mechanisms involved has not yet been established.

It is therefore clear that plant products such as F&V modify the microbiota via their multiple carbohydrate constituents and polyphenols. Given the major role of the microbiota in human health, it is conceivable that some of the beneficial effects of these foods involve the microbiota alongside their classic effects on oxidative stress and metabolism. It would be beneficial to conduct other studies, going beyond their importance in prevention and examining their impact during these established diseases: human clinical intervention studies are expected.

Based on: Han Y., Xiao H. Whole food-based appraoches to modula. Annu Rev Sci Technol. 2020,11:119-43

Flavonoids from fruit and vegetables for improving gut health

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Flavonoids are a specific class of plant-based polyphenols that include the pigmented anthocyanins, as well as flavonols, flavones, isoflavones, flavan-3-ols, and flavanones. They have antioxidant and anti-inflammatory properties. Flavonoids inhibit inflammation stemming from chronic disease. Many studies have described their ability to inhibit intestinal inflammation which has broad implications for the prevention and treatment of chronic disease such as cardiovascular disease, diabetes, Alzheimer's disease, inflammatory bowel disease, and colon cancer[1].

This review aims to provide an update on the gut health benefits of flavonoid consumption by describing flavonoid distribution in foods, their metabolism and bioavailability, and consider mechanisms that may explain their anti-inflammatory activity in the gut.

Flavonoids in fruit and vegetables

Fruit and vegetables are important sources of non-nutrient dietary bioactives including flavonoids. Examples of some flavonoids present in fruit and vegetables are presented in Figure 1. The distribution and profile of flavonoids and other polyphenols varies significantly among different fruit and vegetables. Pre-harvest and post-harvest factors (e.g. plant genotype, food processing, storage) dramatically affect the flavonoid content of food. Thus, consuming a varied diet with adequate levels of fruit and vegetables makes an important contribution to flavonoid intake.

Mechanism: how do flavonoids from fruit and vegetables improve gut health?

It is important to consider the metabolic fate of flavonoids after dietary consumption in order to understand how fruit and vegetables improve gut health. These compounds need to first be released from the plant tissue. Afterwards, flavonoids are absorbed or further metabolized by the host or gut microbiota. A portion of these host and microbial catabolites can be absorbed in the small intestine and colon. When examining the bioavailability of flavonoids, the proportion of metabolites can exceed that of the parent flavonoid compounds.

In turn, flavonoids and flavonoid metabolites impact the microbiota, immune system, and intestinal barrier. Once in cells, these compounds may alter cell-signaling pathways that ultimately reduce oxidative stress and inflammation. Also, flavonoids and flavonoid metabolites can alter the differentiation of immune cells, either directly or indirectly, by modifying the gut microbiota. In rodent models of gut inflammation, flavonoids inhibit the onset of chronic inflammation induced by chemical erosion or from activation of pro-inflammatory T cells.

Work is ongoing in this area, but recent data from human studies have corroborated the anti-inflammatory activity of polyphenols in the gut. Because of the varying flavonoid profiles of fruit and vegetables, it is necessary to continue to build a broad evidence base to establish the specific doses and conditions where fruit and vegetable flavonoids improve gut health.

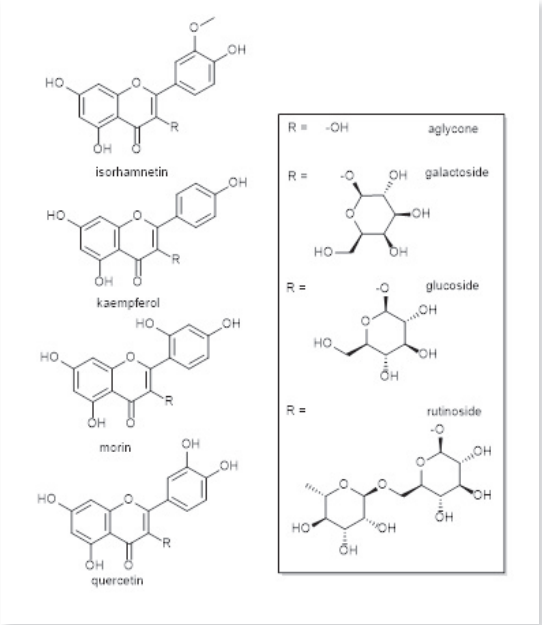

Figure 1. Examples of flavonoids present in fruit and vegetables. These compounds are further metabolized in the gut and may inhibit chronic intestinal inflammation.

Based on: Pei R, Liu X, and Bolling B. Flavonoids and gut health. Current Opinion in Biotechnology. 2020, 61:153-159.

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