Interaction between diet and gut microbiota: an asset for health

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The growing interest in the gut microbiota as a key biological component in health promotion has confirmed over the last few years the crucial role of nutrition in shaping the composition of the microbial ecosystem from early childhood.

This issue of the Global Fruit & Veg Newsletter presents three recent scientific articles that review the link between microbiota and nutrition, illustrating in particular the role of fruit and vegetable constituents targeting the microbiota.

The review of Mentella MC, *et al*. describes the dysbiosis that characterizes inflammatory bowel disease. The review illustrates the role of specific nutrients in the course of the disease. The main message is that the joint characterization of microbiota and nutritional intakes should be carried out in high-quality intervention studies to pave the way for a targeted and personalized nutritional approach in patients with inflammatory bowel disease.

The article of Fan HY, *et al.* presents the results of a pilot study conducted in pregnant women. Higher consumption of fruit and vegetables during pregnancy was shown to have a significant impact on the composition of the newborn's microbiota, assessed two months after birth. The authors indicate which nutrients and plant constituents are inversely correlated with potentially harmful bacteria.

In his review, Shabbir U, *et al.* states the arguments supporting the intake of polyphenols found in fruit and vegetables, which are likely, via their antioxidant effect, but also by modifying the composition of microbiota or via their metabolisation by the microbiota into bioactive compounds, to be able to generate protective effects against cardio-metabolic alterations.

Enjoy your reading. Let's work together to make healthy food choices available to all!

The role of nutrition on Inflammatory bowel disease onset and management, and on gut microbiota composition

Inflammatory bowel disease (IBD), an heterogenous set of inflammatory diseases, is mediated by the immune system, which affect the gastrointestinal tract. Two main IBD manifestations are known: Crohn's disease and ulcerative colitis. An estimation of 3 million people in the US population, representing 1.3% suffers from IBD, with an incidence and prevalence increasing worldwide (Veauthier, 2018; Dahlhamer, 2016). Nevertheless, the etiology of IBD is still not completely understood with several findings showing an interplay of genetic factors, immune dysregulation, and environmental triggers (Dixon, 2015; Leone, 2013). Environmental factors, beyond geographical location, are mainly diet, smoking, alcohol, and drugs (Molodecky, 2012).
This review aims to give further insights on the relationship between nutrition, microbiome, and inflammatory bowel diseases

Microbiota composition changes in patients suffering from Inflammatory Bowel Disease

Diet, lifestyle, hygiene, or antibiotic consumption stimulate rapid and constant changes in gut microbiota composition which can therefore induce a rapid shift in the microbiome. When there is a genetic background predisposition and an intervention of environmental factors, those changes have a pivotal role in determining the onset of IBD as it is clearly associated with intestinal dysbiosis (Lane, 2018).
Studies characterizing the microbiota of patients suffering from IBD indicate a generalized decrease in biodiversity alpha, as well as a reduction in specific taxa including Firmicutes and Bacteroidetes, Lactobacillus and Eubacterium. They also present a reduction in species reducing butyrate wich modulate positively intestinal homoeostasis (Lane, 2018; Franck, 2007; Li, 2015; Christl, 1996).

The impact of specific nutrients on the onset of Inflammatory Bowel Disease

As diet and nutrients are highly associated with the incidence of IBD, the following table address the ilpact of fats, proteins, carbohydrates and fiber on the onset and the progression of the disease (Table 1).

Nutrients	Impact on the onset of IBD	
	Positive impact	Negative impact
Fat	A balanced ratio of ω-3 to ω-6 PUFA is essential for homeostasis because ω-3 is anti-inflammatory whereas ω-6 PUFA is pro-inflammatory (Raphael, 2013).	Long-chain triglycerides are involved in increasing the risk of developing IBD (Miura, 1993).
	Medium chains are anti-inflammatory (Dixon, 2015).	An increased risk of IBD is seen following a high fat diet due both to increased intestinal permeability and to the alteration of the intestinal microbiota (Pendyala, 2012).
Proteins		High protein intake from different sources (red meat, fish, eggs, milk, nuts) may be a factor increasing IBD incidence, but mechanisms remain largely unknown. Some metabolites coming from protein fermentation (e.g., ammonia, total sulfide) seems to be increased in ulcerative colitis patients when compared to healthy subjects (Gilbert, 2018).
Carbohydrates and dietary fiber	Low fiber intake has been associated with increased IBD incidence. Fibers are fermented within the colon where they promote bacterial diversity, preserve mucosal barriers, and prompt the production of short-chain fatty acids that, in turn, positively modulate intestinal homeostasis and reduce inflammation (Christl, 1996).	Observations on humans showed that fructose malabsorption and lactose intolerance are associated with IBD, while observations on anomals reported that high carbohydrates intake favors dysbiosis (Martinez-Medina, 2014; Barrett, 2009).

Table 1 : The impact of specific nutrients on inflammatory bowel disease

The impact of specific diets on microbiota and on the evolution of inflammatory bowel disease

Specific diets	Presentation of the diet	Effectiveness and impact on microbiota
Specific carbohydrate diet (SCD)	Complex carbohydrates are excluded on the basis that when they reach the colon, being still undigested, they cause fermentation and overgrowth of bacteria and yeasts, switching the microbiome toward a pro-inflammatory profile, finally causing IBD. Simple (mono-) saccharides are, instead, included. *Prohibited foods:* milk, grains, soft cheeses, and non-honey sweeteners. *Allowed foods:* unprocessed meats, most fresh vegetables and fruits, all fats and oils, aged cheeses, and lactose-free yogurt.	Robust data, mainly on adults, are lacking to demonstrate the effectiveness of the specific carbohydrate diet. Prospective investigations through case-control studies are needed to get an exhaustive understanding of how this diet may impact the microbiota (Weber, 2019).
Low FODMAP Diet	Similar to SCD, carbohydrates that are poorly absorbed may lead to large intestine dysbiosis, inflammation, fermentation, water secretion and lumen distension. The only difference from SCD is that monosaccharide intake is discouraged. *Prohibited foods:* high-lactose diary, excess fructose vegetables/ fruits/ and food rich in fructans/galactans and polyols. *Allowed foods:* Low FODMAPs foods such as dairy free from lactose, low fructans and galactans from vegetable and low fructose.	Little is known how this approach may impact the underlying inflammation even thought it is currently accepted to use it to treat IBD patients for their irritable bowel symptoms (Weber, 2019).
Gluten-Free Diet	Allowed foods: gluten-free grains from corn and rice, fresh poultry or meat, fruits, vegetables, and dairy.	This diet has a clear role in managing celiac disease, involving elimination of gliadin, but also in subjects suffering from non-celiac gluten sensitivity. However, the benefits of this diet are less clear for IBD patients (Weber, 2019).

Table 2 : The impact of specific diets on inflammatory bowel disease

KEY MESSAGES

• At present, no clear indications toward a specific diet are available.
• The assessment of dysbiosis prior to the recommendation of a specific diet should become a standard clinical approach to achieve a personalized therapy.
• Future perspectives should include investigating the correlation between nutrients and microbiome through appropriate, well-designed, and targeted clinical studies.

METHODOLOGY

• A review 177 publications.

Based on: Mentella MC, et al. Nutrition, IBD and Gut Microbiota: A Review. Nutrients. 2020;12(4):944.

Maternal fruit and vegetable intake during pregnancy influences infant gut microbiome

Maternal nutrition during pregnancy may affect the mother-to-child transmission of bacteria, resulting in gut microflora changes in the child with long-term health consequences later in life. However, evidence supporting the effect of maternal nutrition during pregnancy on the infant gut microbiome remains scarce, and most relevant studies have been conducted on animal models (Chu, 2016).

The following pilot study explored the impact of high/low gestational intakes of fruit and vegetables on the infant microbiome and investigated the interrelationships between maternal nutrient intakes and the abundance of infant gut microbiome taxa.

Maternal fruit and vegetable consumption and their nutrient status

Mothers with high fruit and vegetable consumption had a significantly higher intake of some macronutrients (glucose, fructose, and dietary fibers), vitamins (folic acid and ascorbic acid), and minerals (potassium) compared with mothers with low fruit and vegetable consumption.

Maternal fruit and vegetable consumption was significantly correlated with infant gut microbiome composition

The microbiome of 2-month-old infants varied depending on whether the maternal consumption of fruit and vegetables during pregnancy was high or low (Table 1). Though, other potential confounders such as maternal age and education level, family income, gestational age and weight gain, delivery mode, antepartum antibiotics, group B Streptococcus positivity, sex of the infant and breastfeeding did not impact the infant gut microbiome.

Gut microbiome of 2-month-old infants withhigh maternal fruit and vegetable consumption	Gut microbiome of 2-month-old infants with low maternal fruit and vegetable consumption
Higher abundance of Propionibacteriales, Propionibacteriaceae, Cutibacterium, Tannerellaceae, Parabacteroides and Lactococcus	Higher abundance of Prevotella_2, Prevotella_9, Isobaculum, Clostridia, Clostridiales, Lachnospiraceae, Hungatella, Lachnoclostridium, Ruminococcaceae, Flavonifractor, Erysipelatoclostridium, Acidaminococcaceae, Phascolarctobacterium, Megamonas, Betaproteobacteriales, Burkholderiaceae, and Sutterella

Table 1 : Gut microbiome of 2-month-old infants with high or low maternal fruit and vegetable consumption

Beneficial health effects of Cutibacterium, Parabacteroides, and Lactococcus found in higher abundance in gut microbiome of infants with high maternal fruit and vegetable consumption are demonstrated in the literature, mainly on infant immunity.

• A specie of Parabacteroides, P. distasonis, can improve human bowel health and is negatively associated with celiac disease. An experiment on mice showed that it can also reduce weight gain, hyperglycemia, and liver steatosis whereas another experiment found a significant reduction of the severity of intestinal inflammation of acute and chronic colitis (Sánchez, 2010; Wang, 2019).

• Lactococcus lactis, a specie of Lactococcus, activates innate immunity and protects from infection (Beck, 2015; Kim, 2013). Some Lactobacilli can moreover produce short-chain fatty acids with can modulate gut immune response and thus shape the pulmonary immune environment and influence the severity of allergy inflammation (Du, 2020; Furusawa, 2013; Arpaia, 2013).

Higher maternal intake of fructose, dietary fiber, folic acid, and ascorbic acid are negatively associated with the abundance of unhealthy infant gut microbiome

According to this study, maternal dietary intake high or low in specific macro- and micro-nutrients are associated with the abundance of infant gut microbiome (Table 2).

Results show that higher maternal intake of fructose, dietary fiber, folic acid, and ascorbic acid are negatively associated with unhealthy infant gut microbiomes such as Erysipelatoclostridium, Betaproteobacteria and Lachnospiraceae.

Maternal dietary intake	Infant gut microbiome
Macronutrients	
Fructose	Low abundance of Erysipelatoclostridium
Glucose	An increased abundance of Isobaculum
Dietary fiber	A lower count of Lachnospiraceae
Micronutrients	
Folic acid	A lower abundance of Betaproteobacteria
Ascorbic acid	A higher abundance of *Staphylococcus*
Magnesium	Lower abundance of Clostridia, Clostridiales and Lachnospiraceae
Potassium	

Table 2 : Maternal dietary intake and Infant gut microbiome

KEY MESSAGES

• A diet high in fruit and vegetables during pregnancy may alter the infant gut microbiome.

• A higher intake of nutrients present in fruit and vegetables (fructose, dietary fiber, folic acid, and ascorbic acid) is negatively associated with the abundance of unhealthy gut microbiomes (Erysipelatoclostridium, Betaproteobacteria and Lachnospiraceae).

• Strategies involving increased maternal intake of fruit and vegetable during pregnancy should be employed for modifying the gut microbiome early in life.Strategies involving increased maternal intake of fruit and vegetable during pregnancy should be employed for modifying the gut microbiome early in life.

METHODOLOGY

• Pregnant women from Taipei Mother-Infant Nutrition Cohort who completed a 3-day dietary record and received postpartum follow-up were enrolled in the pilot study (n=39).

• The 16S rRNA gene sequence was used to characterize the infant gut microbiome at 2 months.

• The mean cups of fruits and vegetables were estimated as follows: five cups of fruits and vegetables (the minimum recommended), multiplied by 20% (derived from the average 4.9 g/day divided by the recommended 25g/day of dietary fiber).

• The high or low consumption of vegetables and fruit was determined based on more than one cup of fruits and more than one cup of vegetables per day.

Based on: Fan HY, et al. Maternal Vegetable and Fruit Consumption during Pregnancy and Its Effects on Infant Gut Microbiome. Nutrients. 2021 May 5;13(5):1559.

Polyphenols, gut microbiota, and metabolic diseases

Plant polyphenols are secondary metabolites and a class of non-essential phytonutrients, ubiquitously found in various parts of plants (roots, stems, leaves, flowers, pulp) and abundant mainly in fruit, vegetables, and cereals (Ma, 2020; Rubab, 2020). Their role is vital in human nutrition as they have antioxidant ability and can decrease the reactive oxygen species (ROS) and can be used to improve metabolic disorders such as obesity, diabetes, cancer, and cardiometabolic diseases (Maurya, 2020). Although 90-95% of plant polyphenols are absorbed in the colon, their efficacy (in terms of therapeutic effects) is about 15-20% (Brglez, 2016).

The present review discusses the effect of plant polyphenols in general, with a focus on specific types of polyphenols found in fruit and vegetables, on the composition of gut microbiota that leads to improving overall gut health and improving metabolic disorders.

Gut microbiota and plant polyphenols: a complex and dynamic interplay

According to studies, plant polyphenols and gut microbiota have a dynamic and complex interplay during metabolism contributing to the overall health of individuals (Jamar, 2017).

The retention of plant polyphenols in intestines can promote beneficial effects on gut microbiota. In fact, studies have revealed that plant polyphenols can modulate the colony of gut microbiota by using antimicrobial activity or prebiotic-like effect against harmful gut bacteria (Ozdal, 2016).

On the other hand, gut microbiota enhances the biological activity of plant polyphenols by transforming them into active metabolites (phenolics). Variations in gut microbiota composition are also documented to affect the bioavailability and bioactive effect of plant polyphenols and their metabolites (Espin, 2017).

Figure 1 illustrates major sources of plant polyphanols and their potential health benefits associated with gut microbiota in humans.

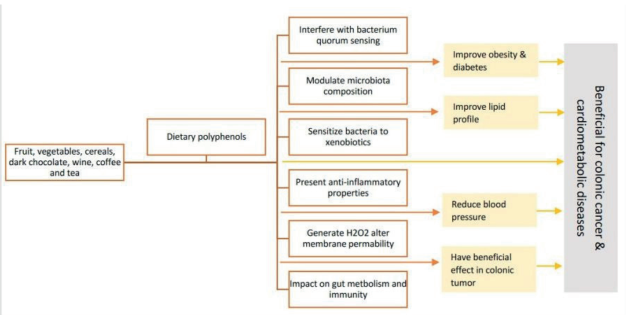

Figure 1. Major dietary sources of polyphenols and potential health benefits associated with gut microbiota (Adapted from Shabbir et al., 2021)

Biotransformation of specific polyphenols found in fruit and vegetables and their effects on human gut

1. Quercetin and gut health

One of the most common flavonoids present in consumer foods, quercetin belongs to the family of flavonoids. It is commonly found in green tea, lettuce, radish leaves, cranberry, apple, onion, coriander, lovage, buckwheat, etc. Quercetin generally acts as a pigment and gives color to numerous fruit and vegetables (Ulusoy, 2020).

About 65-81% of quecertin goes to the liver where it is metabolized and becomes bioavailable (Bischoff, 2008). Complex metabolic reactions in the small intestine and stomach make it bioavailable at less than 10%. Quercetin is transformed into its active metabolites by gut microbiota, mainly by Bacteroides fragilis, Eubacteriumnramulus, and C. perfringens (Figure 2).

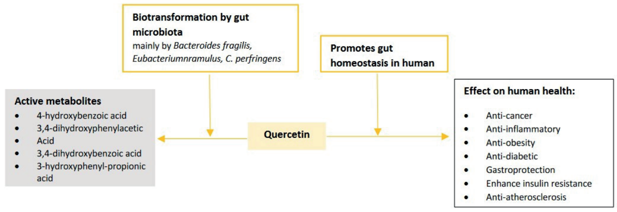

Figure 2: Biotransformation of quercetin into metabolites by gut microbiota and their benefits in gut (Adapted from Shabbir et al., 2021)

2. Catechins and gut health

Catechins are widely found in many foods and herbs (e.g., tea, cacaos apple, persimmons, berries, and grapes). Catechins include epigallocatechin-3-gallate (most abundant and biologically active), epigallocatechin, epicatechin, epicatechin-3-gallate, gallocatechin gallate, and gallocatechin (Khan, 2019).

Once ingested, catechins pass through the small intestine and reach the colon, where they are metabolized from microflora which makes the gut microbiota essential for their biotransformation into their metabolites (Clifford, 2013). Eggerthella lenta and Flavonifractor plautii are mainly responsible for the biotransformation of dietary catechins (Figure 3).

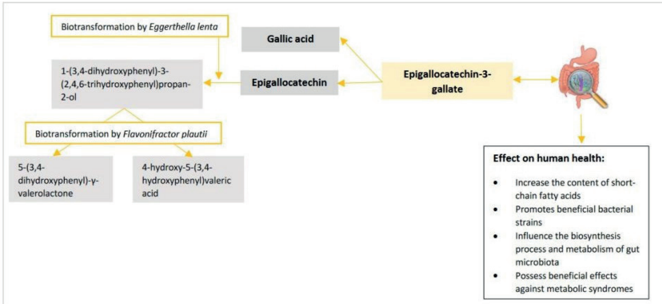

Figure 3: The metabolic pathway and common metabolites of (-)-Epicatechin-3-O-gallate and their modulatory effects on human gut (Adapted from

KEY MESSAGES

• Due to their antioxidative ability, plant polyphenols are known as promising candidates that can prevent and combat several metabolic syndromes.
• As their metabolism occurs in the intestine, retention of plant polyphenols for a long time can promote beneficial effect on gut microbiota.
• In parallel, gut microbiota enhances the biological activity of polyphenols by transforming them into active metabolites that help improving the overall gut health and metabolic disorders.

METHODOLOGY

• Review based on 183 scientific publications

Based on: Shabbir U, et al. Curcumin, Quercetin, Catechins and Metabolic Diseases: The Role of Gut Microbiota. Nutrients. 2021 Jan 12;13(1):206.

The association of specific types of vegetables consumption with 10-year type II diabetes risk: Findings from the ATTICA cohort study

The Greek ATTICA study conducted from 2001 to 2012 among 3,042 healthy adults (Athens) assessed the association between vegetable consumption and the incidence of type 2 diabetes at 10 years. After adjusting for several variables, including general dietary habits, this work shows that participants who consume at least 4 servings of vegetables per day have a 0.42 times lower risk of developing type 2 diabetes. The observed benefits were greater in women than in men. When comparing by type of vegetable, the most significant associations were observed for Alliaceae in women and for red/orange/yellow vegetables and legumes in men.

Kosti RI, et al. J Hum Nutr Diet. 2022 Jun 30.

Regional variation in lifestyle patterns and BMI in young children: the GECKO Drenthe cohort

A study carried out on 1,792 children (3-6 years) in the Netherlands assessed the association between lifestyle and overweight in children. Their environment and socio-economic status were also considered. Diet, sleep duration, screen time and outdoor play were assessed by questionnaires. Sedentary and physical activity levels were measured by accelerometer. Three types of lifestyles were identified: (1) "highly active", (2) "little screen time, lots of sleep and healthy eating", and (3) "lots of outdoor play". Children corresponding to behavior (2) had a reduced risk of being overweight and a lower BMI at 10-11 years of age, regardless of their socio-economic status. Thus, low screen time, high sleep duration and a healthy diet form a favorable combination for preventing overweight in children.

Wiersma R, et al. Int J Health Geogr. 2022 Jul 1;21(1):7.

Human gut microbiota composition and its predicted functional properties in people with western and healthy dietary patterns

A cross-sectional observational study in Poland (200 participants) compared the composition of the microbiota and its functional properties in two groups of volunteers. The first group followed a healthy dietary pattern (n=100), the second a Western-type diet (n=100). The composition of the gut microbiota was different between the two groups. The abundance of potentially favorable gut microbiota was mainly associated with a high consumption of vegetables, fruit, and fiber (higher relative abundance of Firmicutes and Faecalibacterium, lower relative abundance of Bacteroidota and Escherichia-Shigella). Conversely, that of potentially unfavorable gut microbiota is mainly associated with high intakes of added sugars and soft drinks and low fiber.

Malinowska AM, et al. Eur J Nutr. 2022 Jun 24.

The effects of an 8-year individualised lifestyle intervention on food consumption and nutrient intake from childhood to adolescence: the PANIC Study

A study in Finland assessed the long-term effects of an intervention on food consumption and nutrient intake from childhood to adolescence. Participants, aged between 7 and 9 years at the baseline, were followed for 8 years and divided into two groups: intervention (n=306) and control (n=198). In the intervention group, children and their families received personalized support combining counselling and practical application aimed at improving eating habits, increasing the level of physical activity, and reducing the sedentary lifestyle of the family. This intervention improved diet quality from childhood to adolescence. In the intervention group, consumption of vegetables, fruit, and berries and intakes of vitamin C and folate increased. In the control group, vegetable consumption remained unchanged, while fruit and berry consumption, and vitamin C and folate intake decreased.

Sallinen T, et al. J Nutr Sci. 2022 Jun 2;11:e40.

Understanding Impacts of SNAP Fruit and Vegetable Incentive Program at Farmers' Markets: Findings from a 13 State RCT

To facilitate access to healthy food for low-income populations, the federal SNAP programme provides vouchers to purchase certain foods. A two-year randomised controlled trial was conducted at 77 farmers' markets to test the impact of fruit and vegetable (FV) incentive vouchers, randomly issued at varied incentive levels (baseline, moderate, or high) among a group of SNAP recipients (n=2,968). Overall household food purchases and in particular fruit and vegetable purchases, food consumption, food insecurity, health status, market expenditure and demographics were monitored. This work confirms the existing literature. Although 82% of the participants reported food insecurity during the year, this type of financial incentive offered through farmers' markets has significant positive effects on fresh fruit and vegetable consumption. Also, the more the incentive level is high, the more purchases and consumption are high. The authors therefore emphasize the need to include this type of incentive scheme in future policies in order to provide more equitable access for people with limited food budgets.

Karpyn A, et al. Int J Environ Res Public Health. 2022 Jun 17;19(12):7443.