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# Current nutritional guidelines in terms of the effect on gut microbiota and human health considering the WHO and FAO recommendations

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**Abstract:** The purpose of this paper is to evaluate current nutritional guidelines of modern diets based on medical and nutrition facts and their effect on gut microbiota and health, considering current recommendations of world authorities such as FAO and WHO. For this purpose, the first part is devoted to the impact of microbiota on human health, and special attention is committed to the effect of fibre on gut microbiota. The second part is dedicated to the fundamental division of diets and the evaluation of concrete nutritional guidelines of modern diets in terms of microbiota and health, followed by the recommendations of global authorities. Modern diets include diets from the point of view of medical science (e.g. Mediterranean), promoted by nutritionists and authorities (e.g. Nordic) and by social trends (e.g. vegan). The evaluation summarises that high-fibre diets have tremendous benefits on human health. Diets with fresh, local and naturally fermented food (agrarian diets) positively impact the gut microbiota, hence human health. The results of the review show that the nutritional guidelines associated with the lowest mortality are the Mediterranean with the Atlantic or Nordic diet, which is in line with the recommendation of the world authorities (FAO, WHO, UN). The low-fibre western diet with highly processed foods with no or very low levels of live bacteria appears to be high-risk in terms of preventing civilisation diseases with a negative impact on gut microbiota, which is in line with current FAO and WHO guidelines.

**Keywords:** diet; dietary guidelines; food; nutrition; gut microbes; Food and Agriculture Organization; World Health Organization

According to the World Health Organization (WHO), health is 'a state of complete physical, mental and social well-being and not merely the absence of disease and infirmity' (WHO 2006b). Health can be encouraged by healthful activities (e.g. physical ex-

ercise and adequate sleep) and by reducing harmful actions (e.g. smoking and stressful situations). In addition, food's impact on health has been analysed for different purposes for centuries. Even the Greek founder of western medicine, the so-called father

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of medicine, Hippocrates (460 BC – approx. 377 BC), believed that food is our medicine and medicine is our food. These famous quotes attributed to Hippocrates are quoted still today: 'Let food be thy medicine, and let medicine be thy food'; 'Leave your drugs in the chemist's pot if you can heal the patient with food'; 'Just as food causes chronic disease, it can be the most powerful tool' (Wegener 2014). This approach is still relevant regarding food's impact on the microbiome and human health.

The current problem of making the right choice for a healthy diet deal with people with micronutrients and calories deficiencies on the one hand (828 mil people in hunger in 2021) and the trend of increasing numbers of overweight and obese people with compromised health on the other (675.7 mil obese people in 2016, FAO 2022).

The discrepancy provides new challenges to consumers and authorities as they strive to deliver sustainable dietary sustenance. Nutrition is central to the 2030 Agenda for Sustainable Development. People choose from many diets and are influenced by authorities setting trends and regulations in consumption on global, regional and national levels. As globalisation is rising, nutrition trends seem to be global and follow international trends rather than national ones. On a global level, the WHO and the Food and Agricultural Organisation of the United Nations (FAO) set general recommendations, compiled proper nutrition tables, and collected data. On the regional and national level, the choices are conditioned by specific authorities, e.g. European Food Safety Authority, the US Food and Drug Administration, Ministries, State Institutes of Health, Chambers of the Food Industry or Forums. At the same time, nutritional guidelines of modern diets are conditioned by the point of view of medicals (e.g. Atlantic diet, Mediterranean diet), nutritionists (e.g. gluten-free diet) or social trends (e.g. vegan).

In this evaluation, the nutritional guidelines of modern diets are reviewed from the point of view of the effect on gut microbiota and human health, taking into consideration current recommendations of global authorities to provide a summary of which nutritional guidelines can be marked as the best option.

#### **The impact of the microbiota on human health.**

In addition to non-dietary factors (age, gender, stress, gastrointestinal diseases, lifestyle and infections), dietary factors are important for developing and maintaining gut microbiota (Hawrelak and Myers 2004; Gagliardi et al. 2018). Diet and gut microbiota together with the genetic predispositions of the host, can influ-

ence the origin and course of chronic diseases. Diet has an immediate impact on microbiota composition, especially due to the fermentation of polysaccharides and the increased number of butyrate and to her short-chain fatty acids- (SCFA) producing bacteria and the content of specific micronutrients (zinc, vitamins D and A, folate). Deficiency of these micronutrients in childhood may influence the maturation of the gut microbiota and its interaction with the host (Gagliardi et al. 2018). The role of micronutrients on the gut microbiota composition is shown in study with chickens that demonstrated that zinc deficiency provokes changes in the microbial ecosystem composition with a decrease of SCFAs (Reed et al. 2015). Short-term and long-term diet intervention modulates microbiota composition, while on a short-term diet, changes in gut microbiota composition are significant and rapid. Still, the magnitude of changes is modest and insufficient to relocate individuals from one enterotype to another; a long-term diet can relocate enterotypes. If an enterotype is shown to be causative/linked to a disease, long-term dietary interventions could represent a good strategy to improve the course of the disease (Simpson and Campbell 2015). Nowadays, diets drive the gut microbiota composition and metabolome (De Angelis et al. 2019).

Both human and animal studies have demonstrated that pathogens, pathobionts and other microbiome members can respond to a change in their environment by increasing their expression of virulence factors, thereby increasing the pro-inflammatory potential of the microbiota. Acellular nutrients, i.e. nutrients not contained in cells, provide microbial and human cells with more easily digestible substrates that influence human absorption kinetics and are likely to affect intestinal bacterial growth (Zinöcker and Lidseth 2018). Emulsifiers increase virulence factors and the pro-inflammatory potential of gut microbiota, and this low-grade inflammation caused by emulsifiers can promote colon carcinogenesis (Zinöcker and Lidseth 2018; Elizabeth et al. 2020).

**The impact of fibre on microbiota and human health.** A high-fibre diet leads to the colonisation of the gut by the saccharolytic bacteria that ferment carbohydrate residues and fibre to form metabolites (SCFA) that serve as a substrate for colonocytes, a source of potential energy for the host and, in addition, have regulatory effects on colonic mucosal inflammation and proliferation (O'Keefe 2016; Wilson et al. 2020). High fibre consumption maintains colonic health and prevents colon cancer by increasing the proliferative

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capacity of colonocytes and reducing mutagenesis (O'Keefe 2016). Furthermore, high fibre intakes provide high rates of butyrogenesis by the growth of butyrate-producing bacteria. SCFA absorbed into the blood has various epigenetic and immunomodulatory effects in various organs of the human body and thus reduces the incidence and mortality from colorectal, breast or liver cancer (Aune et al. 2011; O'Keefe 2019);, cardiovascular, infectious, and respiratory diseases, diabetes, and obesity (Kim and Je 2016). Gut microbiota alteration and body composition modifications are indirect mechanisms of how diet influences rheumatoid arthritis (RA) onset and progression. A high-fibre diet is the most effective to benefit the metabolome profile by improving the synthesis of chain short-chain fatty acids and decreasing the level of molecules, such as p-cresyl sulphate, indoxyl sulphate and trimethylamine N-oxide (TMAO), associated with the development of diseases (De Angelis et al. 2019).

**The basic division of diets and their effect on microbiota and health.** The colonisation of the gastrointestinal tract (GIT) by gut microbiota (the most studied are bacterial strains) depends on the host's genetic information, among other factors. Microbes already inhabit even the fetal gut, with the most significant changes occurring during the first three years of life (1 000 days after birth) and further development occurring throughout adolescence up to 15–20 years of age. The gut microbiota is then relatively stable; its involution and reduction in diversity then occurs in the final phase of life, in old age (Gagliardi 2018).

It affects gut microbiota balance with bacteria and other living microorganisms in the human gut. These include Archaea, viruses including bacteriophages, fungi, protozoa and multicellular parasites. The mutually beneficial symbiosis of the host and the microbiota is called eubiosis and is the basis of the host's health (the opposite term is dysbiosis, damage to microbial society); for this complex organism (the host and its microbiota), the term holobiont is used. The most represented are these bacterial strains: *Firmicutes* (approx. 60%), *Bacteroides* (approx. 20%), *Actinobacteria* (approx. 20%) and other bacterial strains (*Proteobacteria*, *Fusobacteria*, *Verrucobacteria*, *Cyanobacteria* and others) (Gagliardi 2018).

In addition to the genetic disposition of the host, changes in the intestinal microbiota occur due to external factors, such as the type of delivery, duration of breastfeeding or substitute milk (formula), use of drugs, especially antibiotics, and kind of diet, resp. way of eating. It depends, among other things, on the

fibre content, the amount of saturated fat, the number of carbohydrates, or free sugars (mono- and disaccharides). Another important feature of diets is food processing and the number of microbes, which differ depending on whether the raw material is processed by drying, fermentation, pasteurisation or sterilisation (Gagliardi 2018).

While the diet of prehistoric people contained up to 120 g of fibre, it was not processed, the omega-6:omega-3 ratio was 1:1, and the energy density was  $450 \text{ kJ} \cdot (100 \text{ g})^{-1}$ , the Western-type diet contains 15 g of fibre, it is made up of ultra-processed food, omega-6:omega-3 PUFA (polyunsaturated fatty acids) ratio is 10:1 and the energy density is  $1\,100 \text{ kJ} \cdot (100 \text{ g})^{-1}$  (Jew 2009).

The so-called agrarian diets, vegetarian or vegan diets, Mediterranean or Atlantic diets or Asian diets are closest to the ancestral diet, both in terms of amount and method of processing, amount of fibre, energy density and omega-6 : omega-3 ratio. When consuming agrarian diets, the diversity of intestinal microbiota increases, as well as the proportion of Firmicutes and the amount of SCFA, which positively affects the host's health (Jew 2009; Gagliardi 2018).

Overall, dietary habits can basically be divided into the Western diet (consumed in developed countries of Europe, North America, Australia and in the last decades also in Asia, South America and Africa in the populations that have adopted this way of modern eating including ultra-processed food as multinational companies invest heavily in developing countries) on one hand and, on the Eastern or Asian diet (consumed by a vast population of Asia) with many plant products and fermented food, on the other hand. This is also reflected in microbiota intestinal microbiota composition (Edwards et al. 2015). Western diet is compound of mainly animal products, few plant products, and some cereals, focused on meat and fish, milk and dairy products, and eggs; it is relatively high in saturated fat, sugar and processed foods and low in fresh and fermented fruit, vegetables, low in fibre and antioxidants. The Western diet is on the rise not because of global, regional or national authorities' recommendations (it is highly not recommended by WHO and FAO) but because of the availability of this kind of food (processed food, animal products) to consumer due to trade policies in this century (Kearney 2010) and at the same time due to consumers' income growth, which leads towards more meat consumption (Du et al. 2004). Western diet is associated with the consumption of ultra-processed food, which has been defined as industrial formulations made

entirely or mainly from substances extracted from foods (e.g. oils, fats, sugar, starch, and proteins), derived from food constituents (e.g. hydrogenated fats and modified starch), or synthesised in laboratories from food substrates or other organic sources (e.g. flavour enhancers, colours and several food additives used to make the product hyper-palatable) (Ministry of Health of Brazil 2018). The availability of ultra-processed food is positively associated with the prevalence of obesity (Ministry of Health of Brazil 2018). The low fibre content in the diet leads to a reduction in the diversity of gut microbiota, with specific decreases observed in the abundance of certain taxa, such as *Prevotella*, *Oxalobacter*, *Succinivibrionaceae*, *Paraprevotellaceae*, and *Spirochaetaceae* (Bello et al. 2018). Inflammatory bowel disease (IBD), both Crohn's disease (CD) and ulcerative colitis (UC) were associated with the consumption of a high-fat diet and meat; on the contrary, a vegetarian diet could decrease the risk of IBD by modulating gut microbiota community structure and/or its metabolome (Chapman-Kiddell et al. 2012). Pro-inflammatory gut microbiota (overgrowth of sulphate-reducing bacteria), which develops when consuming large amounts of red meat, is associated with colorectal cancer (CRC) (Magee et al. 2000). Red meat consumption is related to the growth of *Emergencia timonensis* (*Eubacteriaceae*, *Clostridium*, *Firmicutes*), producing TMAO and about total LDL cholesterol levels and coronary heart disease and stroke (Koeth et al. 2019; Wu et al. 2020), this risk seems to be associated with microbial gbu gene cluster (Buffa et al. 2022). From clinical studies it can be seen that consuming the Western diet leads to a major proportion of *Bacteroides* spp. In contrast, diets rich in plant polysaccharides are associated with increased *Prevotella* spp. Elevated dietary intake of fatty meals impacts bile acid homeostasis and colon tumorigenesis (Dermadi et al. 2017). Obese patients on a high-protein/low-carbohydrate diet have reduced intestinal SCFAs and *Bifidobacteria* (Duncan et al. 2007). The environment created in the gut by ultra-processed foods, a hallmark of the Western diet that is recognised as a trigger factor for low-grade systemic inflammatory and oxidative changes, favours the development of neurodegenerative diseases (NDs) (Elizabeth et al. 2020; Martínez Leo and Segura Campos 2020).

In contrast, the Asian diet is rich in fresh and fermented foods, vegetables, fruit, fibre, raw fish and some typical dishes, such as fried foods, rice or noodles, plant products (tofu, algae, bamboo shoots, or lo-

tus roots) and/or fermented foods (miso, kimchi and natto, for example), (Senghor et al. 2018). From studies, it is almost certain that a high-fibre diet, such as vegetables, fruits, and grains, leads to a higher degree of microbiota stability. In adult life, several factors can still disturb gut microbiota balance: food and minor food constituents (contaminants and food additives); prebiotics, probiotics, and symbiotic use; antibiotics and drug intake; and alcohol abuse.

#### **Nutrition governance at the international level.**

On the global level, the message is clear: Poor diets are the leading driver of the global burden of disease (Global Nutrition Report 2016). According to WHO and FAO, poor diet belongs to major factors causing chronic diseases such as cardiovascular diseases, cancers and diabetes (WHO 2006a). Diets have significant effects on health throughout life. For example, 'up to 70% of stroke, up to 80% of cases of coronary heart disease, and up to 90% of type 2 diabetes could be avoided through changing lifestyle factors. Furthermore, up to 70% of colon cancer and about one-third of other cancers could be prevented primarily by eating healthily, maintaining a normal weight and being physically active throughout the lifespan. Most importantly, dietary adjustments may not only influence present health but may determine whether or not an individual will develop such diseases as cancer, cardiovascular disease and diabetes much later in life'. (WHO 2006a). WHO takes the lead on the health cluster and sees a 'healthy diet' (WHO 2008) as follows: Total fat should not exceed 30% of total energy intake; intake of trans-fats (industrially-produced, found in e.g. baked and fried foods, pre-packaged food – frozen snacks, cookies) should be eliminated. Ruminants are found in meat and dairy foods. Industrially produced trans-fats should be avoided) should be less than 1% of total energy intake to eliminate industrially produced trans-fats. Unsaturated fats in diet (found e.g. in fish, avocado, nuts, sunflower, soybean, canola and olive oils) are preferable. Intake of free sugars should be less than 10% of total energy intake. Salt intake (ideally iodised) should be less than 5 g per day to reduce global salt intake by 30% by 2025 (sodium intake of less than 2 g per day), which can prevent hypertension and reduce the risk of heart disease and stroke in the adult population. The diet should include fresh food, so at least 400 g (5 portions) of fruit and vegetables per day. A healthy person should consume about 2 000 kcal per day, where less than 10% of total calories should come from free sugars (added to foods or drinks by a person) and sugars naturally present



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in honey, syrups, fruit and fruit juices, and fruit juice concentrates). FAO and WHO (2019) conclude that the leading risk factors are a low intake of fruit and vegetables, cereals, legumes, nuts and seeds, milk, seafood, n-3 fatty acids, n-6 polyunsaturated fatty acids, calcium and fibre and a high intake of red meat, trans-fats and sodium, which can be summarised, that the Western diet is hazardous, while Asian type diets appear highly beneficial. To harmonise and coordinate guidelines, the UN Standing Committee on Nutrition (UNSCN) was established already in 1977.

**The effects of high-fibre modern diets on human health.** The following diets were chosen based on the recommendations by the UN, WHO, and FAO, who in the current guidelines emphasise the Mediterranean, Nordic or Atlantic diet and are being complemented by the vegan diet, which is very popular by social trends and recommended by the UN regarding sustainability.

Mediterranean diet is a diet with a daily intake of vegetables, fruits, cereals, olive oil, yoghurt or cheese; weekly intake of nuts, legumes, and fish; low amount (weekly or monthly) of red meat; regular intake of water, wine and regular exercise (WHO 2006a). According to the WHO and FAO (2019), the Mediterranean diet is highly recommended as this eating style significantly reduces mortality, especially from cardiovascular disease and cancer. Mediterranean diet could act as an adjuvant therapeutic approach, modulating intestinal microbiota and intestinal barrier function to possibly work as an adjuvant therapeutic approach modulating intestinal microbiota to improve rheumatoid arthritis by the effect of fatty acids (PUFAs), polyphenols and fibre (Dourado et al. 2020). Possible protective effects of some dietary patterns (such as the Mediterranean diet) can be a potential future adjunctive therapy to standard RA treatment (Gioia et al. 2020). These effects also led the Mediterranean Diet to the list of the intangible cultural heritage of UNESCO in 2010 as the most sustainable skill, knowledge, practice and tradition regarding preparation and consumption (WHO 2019).

Mediterranean diet is very similar (in the amount of fibre, focus on fresh food with high amount of cereals, vegetables, potatoes, olive oil, wine, fruits, and seafood) to the Nordic diet (plant-based diet, with little to moderate amounts of animal-sourced foods with high content of local fruits and vegetables, reasonable quantity of native fish, game and fresh regional food) or the Atlantic diet (protein from red meat, eggs, dairy products or vegetables, fresh fish shellfish, as well as cereals and potatoes; the main components include

Vitamin B, omega-3 fatty acids, and iodine (Gagliardi et al. 2018). The Atlantic diet is similar to the Mediterranean and Nordic diets, however the Atlantic diet allows more saccharides than the Mediterranean or Nordic diet, for fruit focuses more on apples and citrus and includes local milk and meat products. When it comes to the New Nordic diet, it is connected with less cardiovascular risk, body fat, inflammatory and cancer risks, as well as lower mortality (WHO 2019). Moreover, these diets are associated with lower environmental impact (reducing water and energy consumption, greenhouse gas emissions and land use). While the Mediterranean diet seems to protect from chronic degenerative diseases, to decrease all cases of mortality, the Atlantic diet has been associated with metabolic health and lower mortality from coronary diseases and some cancers (Sofi et al. 2010; Vaz-Velho et al. 2016; Merri et al. 2020).

Although the vegan diet may be inadequate in caloric value, it is rich in dietary fibre, polyphenols, and antioxidant vitamins and influences the human gut microbiota and health. (Sakkas et al. 2020).

These diets are high in fibre and belong to agrarian diets. They are generally high in fruit/legume fibre and are based on large amounts of cereals (rice, maize, wheat) (Jönsson et al. 2005). Cereals are the most important food source in the world, contributing around 50% of calories globally (Kearney 2010), which can lead undernourished people to this diet.

These diets are usually recommended by medical science and are consistent with the recommendations of the WHO and FAO.

**Comparison of western low-fibre diet and high-fibre diets.** The agrarian diets high in fibre, legumes, fruit, and cereals are associated with greater microbial diversity and a predominance of Firmicutes (*Prevotella*) over Bacteroides. 'Western'-style diets, high in fat/sugar, low in fibre, decrease beneficial Firmicutes that metabolise dietary plant-derived polysaccharides to SCFAs and increase mucosa-associated Proteobacteria (including enteric pathogens). Moreover, bacterial diversity decreases, and bacterial strains (Bacteroides) increase the metabolism of amino acids, the proportion of potentially pathogenic bacteria (*Acinetobacter* spp, *Bilophila* spp, *E. coli* AIEC) that form isobutyrate and isovalerate increases growth, (Simpson and Campbell 2015). Interventions to prevent intestinal inflammation may be achieved with fermentable prebiotic fibres that enhance beneficial Bifidobacteria or with soluble fibre that blocks bacterial-epithelial adherence (contrabiotics). These mechanisms may explain many

differences in microbiota associated with long-term ingestion of an agrarian diet (rich in fruit and vegetable fibre) (Simpson and Campbell 2015).

## CONCLUSION

Nutritional guidelines of modern diets are important for developing and maintaining gut microbiota and can influence the course of chronic diseases. The fibre in diets has tremendous benefits on the microbiome and human health and can be found in Asian types of diets and agrarian diets. Western diet contains less fibre and live bacteria, more sugars and salt due to the high amount of highly processed food. This leads to a decrease in the diversity of intestinal bacteria, maintenance of chronic inflammation and higher risk of civilisation diseases, especially obesity and type 2 diabetes mellitus (DM2), malignant diseases and thus increased mortality. Agrarian diets (Mediterranean, Nordic and Atlantic) appear to be ideal in terms of the effect on gut microbiota and human health, mainly due to fresh plant food (vegetable and fruit intake daily) along with food with live bacteria, a moderate amount of meat, high in cereals (high in fibre) and more varied in oils and legumes. Avoiding trans-fats and using fresh and local food focusing on plants with a moderate amount of meat seems ideal both from the FAO and WHO point of view and the medical science perspective.

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