A Review On Role Of Nutrients In Gut Microbiota

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ABSTRACT

It is remarkably interesting to understand that how the level of gut microbiome is increased by the nutrients of the food, how to develop food products and how to tackle non communicable diseases for the development of the food products. Clinical evidence for micronutrients is less obvious and generally lacking. However, Pretherapeutic evidence suggests that red wine and tea contains polyphenol and vitamin D which can potentially alter the beneficial bacteria. In recent research, there is consistent medical evidence to show that fiber in the diet, such as Arabinoxylans, galacto-oligosaccharides, inulin and Oligofructose, promote the growth of beneficial bacteria and suppress possible preventive species. This medical evidence suggests that the regulation of a permanent/ bacteroids ratio in the gut, both in fat and types are beneficial and potentially determinative. Clinical and preclinical suggestions that adequate amounts and types of protein in the diet have a significant impact on the gut micro- organisms. The effects of micro and macro nutrients on microbiome and metabolome are essential for clinical examination, as well as understanding how it affects the health.

Keywords: Gut microbiota, Gastrointestinal, Non-digestible food, Dietary fiber.

INTRODUCTION

Gut microbiome is defined by Molecular biologist Joshua Lederberg (**Jackson et al., 2018).** Gut microbiota are the microorganism which includes bacteria, fungi and archaea that lives in our digestive system and also in other animals which includes insects also (**Sahmidt et al., 2018).** Escherichia coli is the one of the species of bacteria which is mainly present in the human gut. Largest population of the microorganisms lives in the intestine, which is basically called the gut microbiota. Gut flora is generally started to develop with in one or two years after the birth of human (**Valdes A.M et al., 2018).** Epithelium and mucosal intestinal barriers i.e. secrete have been developed in such a way which is tolerant and supportive to gut flora and provides barriers to pathogenic organisms**. (Sender R et al., 2016)** Relationship between human and gut flora is not harmful coexistence (commensal) but rather a mutualistic relationship. Few microorganisms of the human gut benefit the host by fermenting dietary fiber into short chain fatty acid (SCFA's) like butyric and acetic acid, which are absorbed by the hosts. (**Rosner, 2019)** Gut bacteria plays a very vital role in the synthesizing a variety of nutrients like vitamin B, ssVit K and helps in metabolization of sterols, xenobiotics and bile acids. (**Sender et al., 2016)** When there is a change in diet and a change in

health, the fermentation of the human gut microbiota also changes with the passage of the time. **(McFall-Ngai M et al., 2018)** Nutrients are the compounds of the foods which is necessary for life and as well as for health, it provides energy which is essential for repair and development of the building blocks. Major nutrients are namely carbohydrates, lipids, proteins, vitamins, minerals and water **(Abreu C et al., 2018).**

In ancient times, the effects of metabolism, immunity and neuroendocrine responses are depending upon the hosts gut potential. **(Schmidt T.S et al., 2019)** Fermented, sub or by products acetate, propionate are critical for providing energy to epithelial cells, enhancing epithelial barrier integrity and to provide immunity and protection to pathogens. **(Qin J et al., 2020)** The present investigation is discovering the mechanism of the residential bacterial gene and its potential role in human health and metabolism. The human alimentary tract is divided into several groups known as Phyla. **(Odamaki T et al., 2018)** The gut microbiological consists primarily of four main elements, which includes Frimicutes, Bacteriodetes, Actinobacteria and the Proteobacteria (Belizario et al., 2015). Bacteria reside in the human body, including the mouth cavity, the placenta, the vagina, the skin and the GIT (gastrointestinal tract), while most of the bacteria live within the gastrointestinal tract**. (Paul H.A et al., 2019)** The colon mainly consists of anaerobic bacteria. Due to of different factors the development and alteration of the gut microbiome are affected, which includes birthing and method of infant feeding, stress, exposure, environment, diet, medications, stage of life cycles and diseases like comorbid **(Rogers M.A et al., 2020)**.

Micro communities living in different regions of the human intestine which affects many aspects of health **(Heiman et al.,2017)**. They contribute nutrients and energy to the host through fermentation of the non-digestible food components in the large intestine and are balanced with the host immune system and metabolism in healthy state. **(Qi Yang., 2020)** Although the negative results may include inflammation and infection, involvement gastrointestinal diseases and a potential contribution to diabetes and obesity. There has been great progress in defining a few major members of the microbial community in the healthy large intestine and identifying their roles in the gut metabolism**. (Shortt C et al., 2018)** Moreover, it is clear that diet can have a major impact on microbial community structure over a short and long period of time, opening up new possibilities for health control through diet. It is important to have a better definition of effective commensal bacteria, community profiles and system characteristics that create aa sustainable gut community that yields health benefits **(De Angelis M et al., 2019)**. The extent of inter-personal difference in the microbiological structure with in the population has also become apparent and may affect their reactions to drug administration and dietary manipulation.
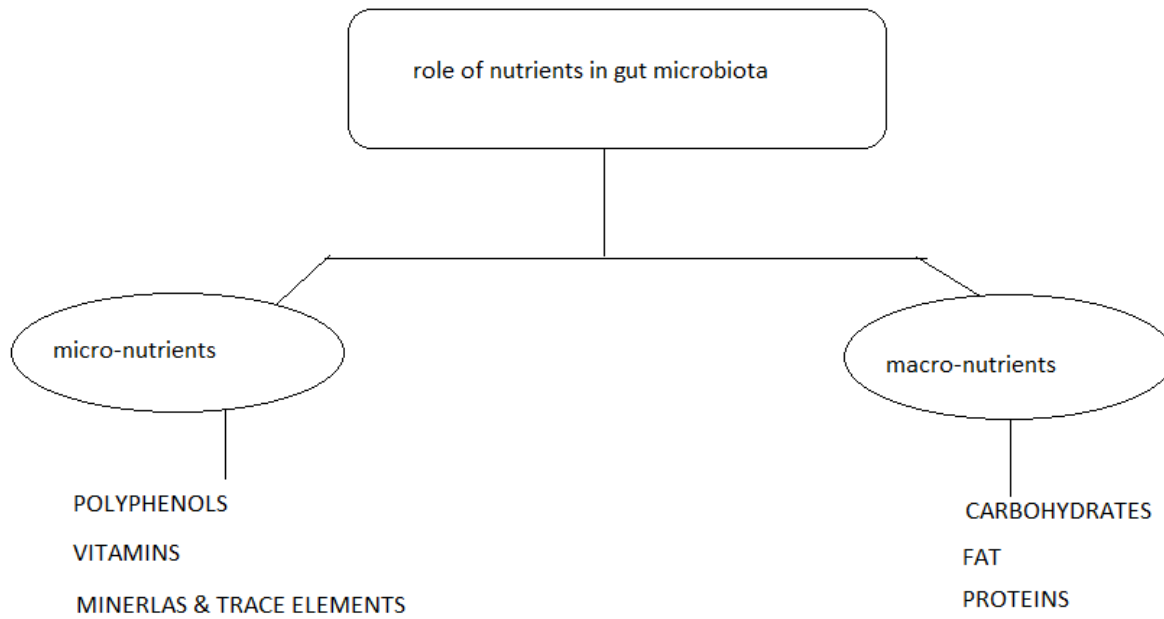
ROLE OF NUTRIENTS IN GUT MICROBIOTA

Figure 1 flow chart of nutrients in gut microbiota (Nash et al., 2020).

MICRO-NUTRIENTS

POLYPHENOLS

Polyphenols like stilbenes, flavonoids phenolic acid, lignans from the fruits, vegetables, tea, grains, coffee and wine, have taken great interest in research due to their molecular, anti-inflammatory and anti-carcinogenic effects **(La Rosa et al., 2019)**. Polyphenols having the capability to modulate the human gut microbiota by preventing or inhibiting the growth of the pathogenic organisms like Helicobacter pylori, Staphylococcus species and promote the growth of the beneficial organisms like Lactobacillus and Bifidobacteria **(Nigro E et al., 2021).**

Flavonoids like Anthocyanins, phenolic acid like coumaric acid and polyphenols like quercetin, rutin etc increase the abundance of the beneficial microbiota and also able to decrease the pathogenic bacteria in the human gut. **(Blesl A et al., 2021)** It was proposed that bio transformed polyphenols promoted the production of short chain fatty acids, which is playing an important role in the health of both gut and metabolism. A flavone like naringenin which is present in the citrus fruits, helps to modulate the growth and genetic regulation of gut non- harmful bacteria. **(He L et al., 2021)** Ethyl acetate which is extracted from the Yunnan Chinese tea also helps to inhibit the growth of un-favorable bacterial species like Clostridium. A few various polyphenols improve the different measures of health by the modulation of the gut microbiota**. (Sivixat S et al.,2021)** Dietary bacteria produce bioactive metabolites by metabolic neurotransmitters and polyphenols that reach the brain across the intestinal obstruction. Specific polyphenols is capable of preventing or increasing the growth of any specific bacteria and which resulting in changes of microbial composition of the gut **(Manoj Gurung, 2020).**

VITAMINS

Gut microbiota produces a variety of nutrients, including SCFA's vitamin B and as well as vitamin K also due to its ability to interact with receptors on epithelial as well as sub epthelial cells, the microbiome also produces a variety of cellular factors which influence human metabolism (**Z Asemi et al., 2019**). Vitamins are the organic compounds which are needed in a very small quantities to support normal body function. Vitamins plays a very vital role in the body from which one of the most important roles is that they act as an co factor for enzymes. **(He L et al., 2021)** Diet is primary source of vitamins as our body cannot synthesize them to meet its daily needs, but certain vitamins, especially vitamin B and Vitamin K are synthesized by a gut microbiota. When there is a deficiency of vitamin, chromic health conditions may increase, and it is very common for peoples to a take lot of vitamin supplements that provide a specific vitamin (**Manoj Gurung, 2020).**

Vitamin A is the fat soluble. It has been indicated as an appurtenant therapy for communicable diseases. **(Sivixat S et al.,2021)** In children with constant diarrhea, variety of dietary microbiota and crucial phylotypes, there is considerable difference between the children with very different levels of vitamin A **(Z Asemi et al., 2019)**. Supplementation of vitamin A is in the form of retinoic acid in a model murine which inhibit the replication of Murine Norovirus. **(La Rosa et al., 2019)** Vitamin A supplementation also helps to decrease both mortality as well as morbidity which is associated with infectious gastrointestinal diseases. It also helps in the reduction of the F/B ratio in children with ASD and helps to increase both Bacteroidetes and Bacteroidales. **(Qi Yang., 2020)** It has been suggested that vit. A supplement to ASD's children has improved the situation, possibly by bringing the Bacteroidetes as well as Bacteroidales population back to their gut. **(He L et al., 2021)** Moreover, a better level of vit A during infancy, and later in life may it influence the health, by enhancing the growth of a healthy microbiota **(Huda et al., 2019).**

Vitamin B are the collection of the eight water soluble vitamins which is very necessary for the different metabolic processes. This vitamin B is easily found in some food like animal-based foods, leafy green vegetables, beans, peas etc. **(Qi Yang., 2020)** By alcohol and by cooking they can be easily reduced few vitamin B have the capability to promote the bacterial colonization and modulate bacterial virulence. Vitamin B12 supplementation enhance the Bacteroides thetaiotamicron in the gut. Moreover, vit. B12 is also very necessary for few enteropathogens for utilization of ethanalomine , which helps in the growthof Salmonella typhimrium. B6 vitamin also produced by the gut microbiota, for various biological reactions Bacteroidetes are utilized as a co-factor which is associated with the immune response of the host. **(He L et al., 2021)** Vitamin B6 is found to reduce the lymphocyte number and impaired antibody responses. B6 vitamin also enhances the growth of Bacteroides, which was either by modulating the host immune system or by interfering with the growth of virulence factors of Salmonella typhimurium **(Nigro E et al., 2021)**.

Vitamin C is another most important water-soluble antioxidant in the human body. Vitamin C cannot synthesize de novo in humans like other water-soluble vitamins and has to obtained from dietary sources i.e is fruits and vegetables via intestinal absorption. **(A Kijmanawat et al., 2019)** Intake of vitamin C was positively correlated with the Firmicutes and its lower taxa i.e. Clostridium and it is negatively associated

with Bacteroidetes in an assessment of a small group of free-living adults with stable cystic fibrosis. **(Wilson et al., 2018)** Vitamin D also found to be positive for health outcomes to help people to maintain health and prevent Chronic diseases and subsequent changes in the microbiota may be a significant mechanism. **(He L et al., 2021)** Vitamin D is a fat soluble and participate in the process of neurotransmitter synthesis and calcium balance protecting nerve cell due to its anti-oxidant effect. Vitamin D helps to prevent even treat different malignant tumors and inflammatory diseases in the gut**. (N Kobyliak et al., 2018)** Vitamin E also well known for antioxidant effect, and it is found in different food products like wheat germ oil, extra virgin olive oil, peanuts, fish, oysters, eggs and butter. Vitamin E helps to protect against mucosal tissue damage in chemical-induced colitis model. Vitamin E also helps in the reduction of Proteobacteria and Firmicutes and production of Bacteriodetes. **(L. Zang et al., 201**9) Vitamin D and vitamin E modulate health beneficial microbes of the Roseburia genera, and both of Vitamin D and vitamin E helps in the reduction of F/B ratio.

MINERALS AND TRACE ELEMENTS

Minerals and trace elements are very necessary micronutrients for human metabolism and actively communicate with the gut microbiomes. **(Kobyliak et al., 2018)** Excess of minerals and trace elements and nutritional deficiency are responsible for different human diseases. Epidemiologically it suggested that intake of calcium in high quantity is associated with a lower prevalence of obesity. **(L. Zang et al., 201**9) Intake of calcium in high quantity also leads to some changes in the gut microbiota, associated with a lean phenotype. High calcium intake modulated gut microiota in a prebiotic manner by increasing the number of Bacteroides/Prevotella. Deficiency of magnesium is associated with an increased incidence of the chronic diseases. **(He L et al., 2021)** It was seen that 4 days of magnesium deficiency reduce the Bifidobacterial content in mouse cecum, but with the prolonged magnesium deficiency in 3 weeks there is an increase in the intestinal content of the bifidovbacteria and lactobacilli.

Iron supplementation is a basic strategy to correct iron deficiency. Iron supplementation decreases decrease the abundance of beneficial microbes and an increased abundance of detrimental microbes. **(Manoj Gurung, 2020)** High dose of iron supplementation reduces the abundance of Bifidobacterium levels compared to the iron supplementation ata alower dose in the infant gut microbiota. **(Qi Yang., 2020)** If iron concentration is decreased the number of commensal bacteria, then there is increase in the number of toxic metabolities and also increases the virulence of pathogenic bacteria. **(Sivixat S et al.,2021)** If the level of iron is rise upto 60 mg/d then it did not significantly change the composition of the fecal microbiome at taxonomic level in overweight as well as women in early pregnancy. Dietary vessels respond differently depending upon the chemical form of iron supplemented dietary iron **(Z Asemi et al., 2019)**.

Phosphorous is the second most abundant inorganic substance in the body and plays very vital role in maintain the equilibrium of systemic acid of the blood. **(Qi Yang., 2020)** 700-1000mg for adults is the recommended intake of phosphorous, but when processed foods like baked goods and sugar sweetened beverages are consumed than the iron intake level exceeds. **(Z Asemi et al., 2019)** For maintaining the epithelial integrity the zinc is an essential micronutrient by modulating the beneficial gut microbiota. Lack

and excess of Selenium is related to health conditions, like increase in mortality, risk of type 2 diabetes and cancer. **(Sivixat S et al.,2021)** There is limited evidence that certain systems in which the gut microbiota is converted by microorganisms into minerals and help in detecting the elements.

MACRO NUTRIENTS

CARBOHYDRATES

Many complex carbohydrates are degraded and fermented in large intestine by human dietary microbiota. In the human intestine, there is a complex relationship in the intestine between microbiota, diet and host. **(Blesl A et al., 2021)** Research on the combination and efficiency of carbohydrates and dietary microorganisms is fast evolving and can open opportunities for prevention and treatment of obesity, diabetes and other associated metabolic disorders through gut ecology. **(Z Asemi et al., 2019)** When the dietary bacteria digest carbohydrates, then they release short chain fatty acids, which have positive health effects like swelling and also reducing the risk of colon cancer. Fermented fibers like pectin, beta glucans, beta fructans, inulin and some resistant starches are fermented by the intestinal microbiota to produce a variety of beneficial substances which includes short chain fatty acids. **(Qi Yang., 2020)** Carbohydrates are the major energy sources for the human body and they play an important role in shaping the gut microbiota. The plant-based carbohydrates that are classified as dietary fibers to avoid digestion in the upper digestive tract and are classified as nutrients in their structures as well as effects which are fermented by large intestinal bacteria. **(Sivixat S et al.,2021)** A chronic lack of dietary fiber could reduce the diversity of gut microbiota. High fiber diet inventions like whole grain cereal, inulin and fructo-oligosaccharide mixed fiber in the ratio of 1:1, soluble corn fiber, barley kernel bread, increases the fecal abundance of different beneficial micriobiota, like Bifidobacterium sp., Lactobacillus sp., Akkermansia sp., Fecalibacterium sp., etc. diets which are enriched in fiber they reduce the F/B ratio and improve the gut microbioal diversity. **(Z Asemi et al., 2019)** The bacteriodetes lower in obese people compared with that in lean people and also increased on a carbohydrate restricted low calorie diet for annual and responded to the weight loss. Arabinoxylans, Arabinoxylanoligosaccharides are commonly found in the wheat are prebiotics, and they increase the beneficial microbiota which includes Bifidobacterium and Lactobacillus. **(Qi Yang., 2020)** Resistant carbohydrats plays very vital role in supporting the health of the gut as it is used by the beneficial gut pathogens. Dietary starch modulates the health beneficial microbes in both animals and as well as in humans **(Blesl A et al., 2021)**.

FAT

It seems to be a more saturated or matrix of total fat that has persistent side effects on intestinal microbiome. The diets which are high in total fat and saturated fat those have negative effect on the richness and diversity of the gut microbiota. **(Blesl A et al., 2021)** It has been found that consumption of 40% of the fat by healthy young adults associated with unfavorable changes in the gut microbiota, in that the intervention results in an increased abundance of the detrimental sp., from the bacteria Bacteroides and Alistipes . **(Sivixat S et**

al.,2021)   The two species are abundant in patients with type 2 diabetes mellitus and decreased abundance of beneficial bacteria of the genus Fecalibacterium. 20% of the consumption of the fat shows a positive effect in increasing gut microbiota Fecalibacterium sp and Blautia sp. The peoples who have diseases like metabolic, obesity and heart diseases that lower fat intake to less than 35% for 2 years that will help to restore the gut microbiome **(Blesl A et al., 2021)**. The saturated dietary fat changes conditions for gut microbial assemblage by enhancing changes in host bile composition, resulting in dybiosis that can perturb immune homestasis. **(Z Asemi et al., 2019)** Saturated fats, medium chain fatty acids shows the antibacterial effects. Olive oil is high in unsaturated fatty acids, and it is increasing the non-harmful bacteria, and the population of Bacteroidaceae, in the cecum, which is compared with palm oil, fish oil as well as flax seed oil. Akkermansia and Bifidobacterium were also considered to be associated with prebiotic consumption and they were decreasing the influence of HFD **(Blesl A et al., 2021)**. Enteral supplementation with poly unsaturated acids decreases the abundance of detrimental bacteria like Streptococcus sp, greater bacterial diversity in premature infants with an enterostomy. Both quantity as well as type of fat in diet modulate the F/B ratio and they both affect the detrimental and beneficial microbes in the gut. **(Nigro E et al., 2021)** Saturated fats increases the F/B ratio and unsaturated fat lowers the F/B ratio, and they have different effects on human health depending on the fat quality.

PROTEIN

Proteins in the diet having the substantial effects on the gut microbiota. Dietary protein and metabolic amino acids are essential nutrients for humans and animals. **(Nigro E et al., 2021)** The dietary microbiota is in the intermediate stage of the cross talk between the protein metabolism and the host immune response. Gut germs take part in the process of digestion, absorption, metabolism and conversion of dietary protein into gut. Ammino acids is digested in many micro-biological metabolities and these metabolities participate in various bodily functions relating to the health and diseases of the body. **(Blesl A et al., 2021)** Constituents of dietary protein influence dietary microbiological combination and microbial metabolism. The source of dietary protein, concentration and ammino acids balance help in the structure and function of the gut microbes. A suitable ratio between ammino acid and starch or even a low ammino acid is recommended over a diet with protein in excess of requirements greater levels and non-digested proteins lead to the growth of pathogenic organisms with high risk of metabolic diseases **(Blesl A et al., 2021)**.

It involves the narrowing of the cavities between the protein and gut microbiota structure and function, which will help to reveal the possible mechanism of the gut pathogens on the health of the gastrointestinal tract **(Sivixat S et al.,2021)**.

CONCLUSION

We are entering an age where we can rapidly modify health through food and measures influences through micro-organisms or metabolite. Fiber is a major nutrient for healthy microbiome and has been ignored while the effects of sugar and fat have been raged. Microbiology of drugs and processed food materials cannot be

ignored. In view of the present limitation of knowledge, we require clinical facts, ideally used in clinical practice, in order to assess the combination of gut microbiota and the change in the health outcomes.

REFERENCES

Jackson, M. A., Verdi, S., Maxan, M. E., Shin, C. M., Zierer, J., Bowyer, R. C., ... & Steves, C. J. (2018). Gut microbiota associations with common diseases and prescription medications in a population-based cohort. *Nature communications*, *9*(1), 1-8.

Schmidt, T. S., Raes, J., & Bork, P. (2018). The human gut microbiome: from association to modulation. *Cell*, *172*(6), 1198-1215.

Valdes, A. M., Walter, J., Segal, E., & Spector, T. D. (2018). Role of the gut microbiota in nutrition and health. *Bmj*, *361*.

Rajagopala, S. V., Yooseph, S., Harkins, D. M., Moncera, K. J., Zabokrtsky, K. B., Torralba, M. G., ... & Nelson, K. E. (2016). Gastrointestinal microbial populations can distinguish pediatric and adolescent Acute Lymphoblastic Leukemia (ALL) at the time of disease diagnosis. *BMC genomics*, *17*(1), 1-10

Ardisson Korat, A. V., Li, Y., Sacks, F., Rosner, B., Willett, W. C., Hu, F. B., & Sun, Q. (2019). Dairy fat intake and risk of type 2 diabetes in 3 cohorts of US men and women. *The American journal of clinical nutrition*, *110*(5), 1192-1200.

Vitellio, P., Celano, G., Bonfrate, L., Gobbetti, M., Portincasa, P., & De Angelis, M. (2019). Effects of Bifidobacterium longum and Lactobacillus rhamnosus on gut microbiota in patients with lactose intolerance and persisting functional gastrointestinal symptoms: A randomised, double-blind, cross-over study. *Nutrients*, *11*(4), 886.

Petersen, J. M., & Osvatic, J. (2018). Microbiomes in natura: importance of invertebrates in understanding the natural variety of animal-microbe interactions. *Msystems*, *3*(2).

Douglas, A. E. (2018). Which experimental systems should we use for human microbiome science?. *PLoS biology*, *16*(3), e2005245.

Abreu, C., Ortiz Lopez, A., & Gore, J. (2018). Pairing off: a bottom-up approach to the human gut microbiome. *Molecular systems biology*, *14*(6), e8425.

Odamaki, T., Bottacini, F., Mitsuyama, E., Yoshida, K., Kato, K., Xiao, J. Z., & van Sinderen, D. (2019). Impact of a bathing tradition on shared gut microbes among Japanese families. *Scientific reports*, *9*(1), 1-8.

Wong, C. B., Odamaki, T., & Xiao, J. Z. (2019). Beneficial effects of Bifidobacterium longum subsp. longum BB536 on human health: Modulation of gut microbiome as the principal action. *Journal of Functional Foods*, *54*, 506-519.

Blesl, A., & Stadlbauer, V. (2021). The Gut-Liver Axis in Cholestatic Liver Diseases. *Nutrients*, *13*(3), 1018.

Gurung, M., Li, Z., You, H., Rodrigues, R., Jump, D. B., Morgun, A., & Shulzhenko, N. (2020). Role of gut microbiota in type 2 diabetes pathophysiology. *EBioMedicine*, *51*, 102590.

Newman, N. K., Monnier, P. M., Rodrigues, R. R., Gurung, M., Vasquez-Perez, S., Hioki, K. A., ... & Shulzhenko, N. (2020). Host response to cholestyramine can be mediated by the gut microbiota. *bioRxiv*.

Korotkyi, O., Kyriachenko, Y., Kobyliak, N., Falalyeyeva, T., & Ostapchenko, L. (2020). Crosstalk between gut microbiota and osteoarthritis: A critical view. *Journal of Functional Foods*, *68*, 103904.

Probiotics and nutraceuticals as a new frontier in obesity prevention and management. *diabetes researc*Okazaki, F., Zang, L., Nakayama, H., Chen, Z., Gao, Z. J., Chiba, H., ... & Shimada, Y. (2019).

Kobyliak, N., Falalyeyeva, T., Boyko, N., Tsyryuk, O., Beregova, T., & Ostapchenko, L. (2018). Microbiome alteration in type 2 diabetes mellitus model of zebrafish. *Scientific Reports*, *9*(1), 1-10.*h*

Kobyliak, N., Abenavoli, L., Falalyeyeva, T., Mykhalchyshyn, G., Boccuto, L., Kyriienko, D., ... & Dynnyk, O. (2018). Beneficial effects of probiotic combination with omega-3 fatty acids in NAFLD: a randomized clinical study.*and clinical practice*, *141*, 190-199.

Kobyliak, N., Falalyeyeva, T., Mykhalchyshyn, G., Kyriienko, D., & Komissarenko, I. (2018). Effect of alive probiotic on insulin resistance in type 2 diabetes patients: randomized clinical trial. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, *12*(5), 617-624.

Kobyliak, N., Falalyeyeva, T., Boyko, N., Tsyryuk, O., Beregova, T., & Ostapchenko, L. (2018). Probiotics and nutraceuticals as a new frontier in obesity prevention and management. *diabetes research and clinical practice*, *141*, 190-199.

Korotkyi, O., Kyriachenko, Y., Kobyliak, N., Falalyeyeva, T., & Ostapchenko, L. (2020). Crosstalk between gut microbiota and osteoarthritis: A critical view. *Journal of Functional Foods*, *68*, 103904.

Wang, J., Chen, W., Zhong, H., Luo, Y., Zhang, L., He, L., ... & Li, L. (2021). Identify of promising isoquinolone JNK1 inhibitors by combined application of 3D-QSAR, molecular docking and molecular dynamics simulation approaches. *Journal of Molecular Structure*, *1225*, 129127.

Nigro, E., Perrotta, F., Scialò, F., D'Agnano, V., Mallardo, M., Bianco, A., & Daniele, A. (2021). Food, Nutrition, Physical Activity and Microbiota: Which Impact on Lung Cancer? *International Journal of Environmental Research and Public Health*, *18*(5), 2399.

Bozzetto, L., Polito, R., Nigro, E., Prinster, A., Della Pepa, G., Costabile, G., ... & Annuzzi, G. (2021). Dietary influence on adiponectin in patients with type 2 diabetes. *European Journal of Clinical Investigation*, e13548.