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Inulin and its Effect on Inflammation Markers: A Literature Review

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Inulin is a prebiotic that helps modulate various functions in the host organism through multiple systemic and local pathways. It modulates the microbiota, promoting the presence of bifidobacteria, also influence on lipid homeostasis. It occurs due to the interaction of its degradation metabolites with diverse metabolic pathways or components, such as the microbiota and intestinal barrier, or by promoting the growth of specific beneficial microorganisms. A notable effect of prebiotics is their influence on inflammation markers, mainly IL-6 and TNF-a, which are elevated in multiple pathologies and negatively impact health; this effect could be by the direct effect of inulin on the decrease in the expression of inflammatory factors such as NF-kB, TNF-a, and IL-6, and depends on the inhibition of the NF-kB pathway. In obesity there is a chronic inflammation with increase of TNF-?? and the lipopolysaccharides has a role in developing insulin resistance, diabetes, and obesity; inulin seems to have an effect on both. Also, due to its effect on inflammation markers, it could also have a beneficial effect in the case of inflammatory bowel disease. It is needed to know the effect of inulin on diabetes and depression among others diseases where inflammation markers are increased. Apparently the benefits of inulin on various diseases are due to its effect on the intestinal microbiota and on inflammation markers. This review focuses on summarizing inulin's effects on inflammation markers and it opens the possibility to research the effects of inulin in the human health against many diseases.

Keywords: Dysbiosis; Inflammation markers; IL-6; TNF-alpha; Inulin; Microbiota.

With advances in understanding the microbiota, the potential for manipulating it to treat or prevent diseases has garnered growing attention from the scientific community.[1] This is based on the human intestine's fundamental role in various physiological functions [2] and the increasing prevalence of chronic diseases associated with diet and a deficient intake of dietary fiber, among which obesity, metabolic syndrome, type 2 diabetes, and cardiovascular diseases stand out. [2]

Dietary fibers classified as prebiotics are substrates used selectively by host microorganisms, especially by the intestinal microbiota, which confer health benefits.[2] Currently, prebiotics and probiotics are popular research topics on microbiota modulation [1] and have been used in

various interventions when administered orally as dietary supplements.[2]

One prebiotic of notable interest is inulin, widely recognized for its properties. Inulin is a cost-effective, safe alternative to drugs for preventing and managing intestinal flora imbalances and inflammation-related diseases.[3]

Inulin impacts gastrointestinal functions, including modulating microbiota composition (bifidogenic effect), improving the intestinal barrier,[4,5] participating in neuroendocrine pathways[6], and enhancing mineral absorption.[2,6,7] Additionally, it influences systemic functions such as lipid homeostasis[8] and immunomodulation,[9] underscoring its role in maintaining or recovering health.[7]

It is capable of modulating the gut microbiome and chronic inflammation resulting from metabolic abnormalities and gut flora dysfunction plays a significant role in the development of type 2 diabetes mellitus (T2DM), and its effect was showed in animals models[3] but those effects should be demonstrated in humans.

Also, one effect of prebiotics is on inflammation markers as Interleukin-6 (IL-6) and tumor of necrosis factor- alpha (TNF-á),[5] and these markers have influence in human diseases, as obesity, diabetes, inflammatory bowel disease, among other.

Our objective was to review the evidence of the effects of inulin on inflammation markers and on health in general.

METHODOLOGY

We searched articles on Pubmed®, Clinical Key®, and Google Schoolar® with the words: probiotic AND inflammation, inulin AND inflammation markers, inulin AND IL-6; inulin AND TNF-5ØÂÞ, inulin AND obesity, inulin AND diseases.

Inclusion criteria

The articles included were those that mentioned the effects of inulin as a probiotic in humans and in the diseases that occur in them, focusing on those that mentioned the effects on inflammation markers.

Exclusion criteria

Articles that mentioned other probiotics were not included.

RESULTS

Inulin

Inulin is a storage carbohydrate composed mainly of fructose molecules linked by â(2'!1) bonds, which cannot be cleaved by human intestinal enzymes and is classified as dietary fiber.[7,10]

It was first described in the roots of elecampane (Inula helenium) by the German scientist Valentine Rose in the early 19th century. By 1917, Thomson named it "inulin".[10]

Inulin sources

It occurs naturally in approximately 36,000 plant species. The chief sources of inulin belong to dicotyledonous and monocotyledonous families such as *Gramineae*, *Liliaceae*, and *Compositae.*[10] The two most well-known sources are from the Compositae family (Jerusalem artichoke, onion, garlic, leeks) and the Asteraceae family (chicory, burdock root).[6,10-12] However, it has also been studied in wheat, asparagus, and bananas.[14] Additionally, some microorganisms produce it, including the naturally known bacterial species *Streptococcus mutans*.[11] In laboratory studies, certain fungal species, particularly members of the Aspergillus family, have been shown to produce inulin,[11] a finding that remains somewhat controversial.

Regarding its location in plants, inulin is mainly found in 3 regions: in the root, tuber, and bulb.[10] Puhlmann et al. discovered that inulin is encapsulated in a complex wall of pectin, cellulose, and hemicellulose.[12] Properties such as chain length and polydispersity depend on the source, time of harvest or point in the life cycle, climatic conditions, growing season, and storage.[6,11]

Potential Uses

The chemical name of inulin is á-D-glucopyranosyl-â-D-fructofuranosyl-D-fructofuranoside. It is a polymer formed by a fructose chain that ends in a reducing glucose end. Various plants synthesize it for energy storage.[10]

The potential uses of inulin in the pharmaceutical and food industries arise from its chemical and physical properties. First, soluble inulin is chemically stable and has no toxicity.[10]

The â(2 '! 1) bonds hinder digestion in humans and other higher animals lacking the necessary enzymes. However, some

microorganisms with inulinase activity that exist in the intestine are capable of digesting it, with the subsequent production of essential metabolites. These characteristics position it as a valuable prebiotic dietary fiber.[10] Additionally, it positively affects the physiological functions of the colon, increasing the fecal biomass, which in turn helps regulate bowel movements.[7]

Due to the hydroxyl groups in its molecular structure, it can interact with water, which gives it surfactant-like properties and allows it to form stable hydrogels.[10] These hydrogels provide characteristics similar to the fat texture. It enables its use as a fat replacer, resulting in low-fat foods pleasing to the palate and a good mouthfeel.[10]

As for solubility, this is in inverse proportion to the chain extension, that is, shorter chains have greater solubility.[11] The short chains are used in the food industry for the manufacture of gels that are used to provide texture and volume.[10] In addition, by providing between 30-50% of the sweetness of table sugar, it is used as a sugar substitute in cereals, cookies, fruit yogurts, and frozen desserts.[2]

In contrast, long chains with low solubility tend to have a creamy texture, making them ideal for functioning as fat replacers in spreads, baked goods, dairy products, frozen desserts, and dressings[2]. Another application of long inulin chains is activating the complement system, and they can also be used as adjuvants in vaccines or cancer treatment.[2,10,11]

Likewise, it is used in the production of alcohols, glycerol, or detergents.[10]

Inulin as a prebiotic

Prebiotics are a group of substrates that are selectively used by host microorganisms and confer health benefits. Inulin-type fructans (native inulin, short-chain fructooligosaccharides, and oligofructose), galactooligosaccharides, and lactulose are recognized as prebiotics. Furthermore, all prebiotics can be classified as dietary fibers.[2]

For a food or food ingredient to be classified as a prebiotic, it is necessary to scientifically demonstrate several properties; such as resistance to gastric acidity, hydrolysis by enzymes in mammals and intestinal absorption; fermentation by the intestinal microbiota; and the selective stimulation of the growth and/or activity of intestinal bacteria associated with health and well-being, which mainly include lactobacilli and bifidobacteria.[7,13]

Thanks to its B (2-1) glycosidic bonds, inulin is known as an indigestible oligosaccharide,[10] as it can pass almost intact through the human digestive system. Once it reaches the large intestine

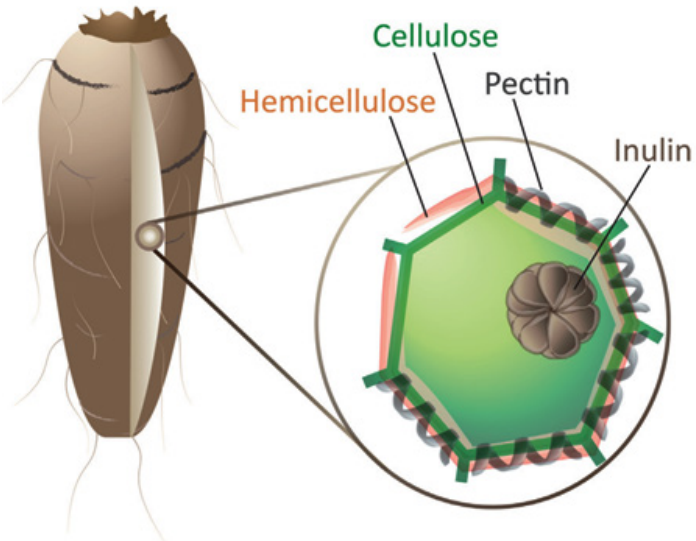

Fig. 1. Representation of inulin localization. Inulin is within a complex wall composed of pectin, cellulose, and hemicellulose.
Source: Taked from Puhlmann et al.[12]

it is digested, mainly by bifidobacteria, resulting in several short-chain fatty acids (acetate, propionate, and butyrate) that are used as energy sources.[6,10]

The gastrointestinal degradation of inulin depends on the degree of polymerization.[2] In this sense, inulin-type fructans are classified into subgroups depending on the number of fructose units. Those that contain 3-5 fructose units (UF) are called "relatively small", "medium" 6-10 UF, and "long" 11-60 UF 7. Shorter chains are fermented faster in the distal ileum or proximal colon.[2,7]

Long-chain inulin has been found to offer more significant benefits in regulating the intestinal microbiota as it promotes the growth of species such as *Bacteroides*, *Parasutterella*, and *Eryspelatoclostridium*, which are capable of processing complex polysaccharides.[14]

However, various factors have been found that influence the prebiotic effects of inulin-type fructans (FTI); such as the source, chain length, dose, initial fiber consumption, or the initial constitution of an individual's intestinal microbiota, mainly the proportion of Bifidobacterium. [2,7]

On the other hand, the most reported side effects associated with its consumption are flatulence, increased frequency of defecation, abdominal pain, and longer intestinal transit times.[2] Among these, abdominal pain scores are dose-related.[2]

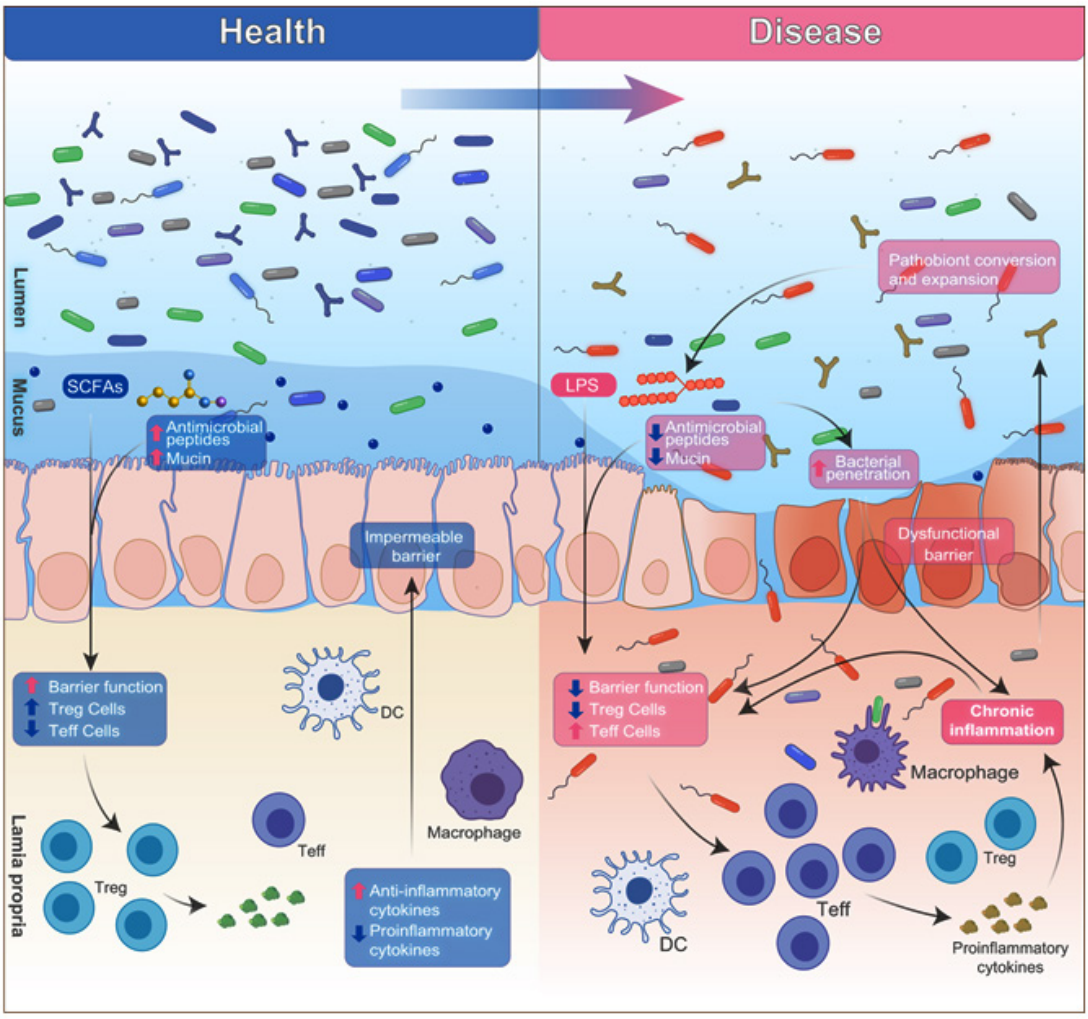

Fig. 2. Interactions between the microbiota and the host.
Source: taken from Hou K, et al.[1]

The effects of inulin and its metabolites on the microbiota

The human intestinal microbiota is made up of commensal microorganisms that reside in the digestive system, especially in the large intestine,[6] This microbial community includes nearly 1,000 species, mostly bacteria, that contain vast genetic potential, as they have up to 150 times more information than the human genome.[1,11] When healthy conditions exist, there is a symbiotic relationship,[1] in which the host provides nutrients and the bacteria offer essential benefits to the host by exhibiting stability, and resilience.[6]

The normal microbiota is composed of 90% of four dominant phyla: *Firmicutes, Bacteroidetes, Actinobacteria*, and *Proteobacteria*, along with other minor phyla such as *Fusobacterium* and *Verrucomicrobia. Firmicutes* are Gram-positive bacteria. *Bacteroidetes* are a group of Gram-negative bacteria that can ferment indigestible carbohydrates. Actinobacteria are Gram-positive bacteria, which includes the genus *Bifidobacteria*. They are generally considered beneficial.[15]

It performs essential functions in the body, as it participates in the defense against external pathogens thanks to the production of antimicrobial substances, participates in enteroendocrine signaling, and is a dynamic component of the intestinal mucosa and the immune system. Likewise, it participates in the biosynthesis of vitamins, amino acids, and lipids. [1,14]

Its fundamental role is the degradation of dietary fibers, including fructans such as inulin, which upon reaching the colon and the distal region of the gastrointestinal tract are fermented into short-chain fatty acids (SCFAs), which are carboxylic acids with aliphatic chains on the carbons. [10,11,16] Within which, acetate (C2), propionate (C3), and butyrate (C4) represent 95% and are found in a 3:1:1 ratio. [16, 17.]

These SCFAs are responsible for local biological effects on the surface of the intestinal epithelium and/or in the homeostasis of immunity; and at a systemic level in the host. [6, 10, 11]

SCFAs enter cells by various mechanisms; The first is by passive diffusion, the second is with the help of transporters and the third is through the activation of G protein-coupled receptors (GPCRs).[16,17] Once absorbed, SCFAs are used by enterocytes as a source of energy or transported into the bloodstream to other peripheral organs and tissues[15] such as adipose tissue,[18] skeletal muscle, and the liver.[17,19]

SCFAs provide energy to the epithelial colon cells,[6,15] serve as substrates in hepatic metabolic pathways,[20] and act as signaling molecules that bind to enterocytes, promoting the release of postprandial intestinal hormones involved in regulating blood glucose levels and body weight[6]. They also help circulate free fatty acid levels and improve the lipid profile.[8,9]

Effects of Inulin on Inflammation

Chronic inflammation plays an important role in the pathogenesis of various diseases[1] such as inflammatory bowel disease, cancer, autoimmune diseases, and metabolic and neurogenic disorders.[21] In this context, intestinal dysbiosis is linked to alterations in inflammatory markers, characterized by a deregulation of nuclear factor kappa B (NF-kB) resulting in considerable expression of cytokines such as tumor necrosis factor-alpha (TNF-alpha) interleukin 6 (IL-6) and interleukin 8 (IL-8) mainly.[1] Figure 2 exemplifies the relationship in health and disease scenarios between the intestinal barrier, the microbiota, and the immune response.

The intestinal microbiota plays a primary role in the development and function of the immune system, in addition to regulating inflammatory processes both locally and systemically. This is achieved thanks to the interaction between epithelial, dendritic, and immune T and B cells;[2,21,22] mediated by components of microbial cells such as lipopolysaccharides (LPS) and some metabolites, among which butyrate, a short-chain fatty acid, stands out. [2]

A bacterial translocation involving components of the outer membrane of Gram-negative bacteria, known as lipopolysaccharides, affects the normal functioning of the intestinal barrier and is manifested by an increase in serum markers of intestinal permeability and triggers proinflammatory reactions involved in intestinal diseases and systemic.[23]

Inulin supplementation improves the integrity and function of the intestinal barrier, as it has a positive regulation on tight junction proteins (claudin-1 and occludin-1) and adapter proteins (zonulin-1), which are crucial components of the intestinal barrier.[24] It also helps reduce bacterial translocation and lipopolysaccharide

Table 1. Pathologies that can be modified by inulin

Obesity[35,37]
Inflammatory bowel disease[41]
Diabetes[3]
Polycystic ovary syndrome[45]
Depression[48]

Source: Own design

endotoxemia.[25] Furthermore, inulin administration enhances IgA secretion and promotes the secretion of mucin glycoproteins (MUC2), the main constituents of the intestinal mucous layer, through butyrate binding to G protein-coupled receptors, improving the intestinal barrier function.[5,24] In addition, it regulates the integrity of the intestinal barrier through the secretion of IL-8 and antimicrobial peptides by epithelial cells.[17]

The antigenic components of Gram-negative bacteria, lipopolysaccharides (LPS), bind to Toll-like receptor 4 (TLR4), which is present in both immune and non-immune cells and the vascular endothelium.[24] These cells participate in innate and adaptive immune responses and coordinate inflammatory responses.

A high activation of TLR4 leads to sepsis, septic shock, and death, secondary to infections by Escherichia coli and Pseudomonas aeruginosa. On the other hand, low activation of TLR4 results in metabolic endotoxemia with subsequent chronic low-grade inflammation, which promotes the development of diseases such as cancer, type 2 diabetes, and neurodegenerative conditions.[24]

The TLR4 signaling pathway activated by LPS begins when LPS binds to the TLR4 receptor on the cell membrane, triggering an intracellular signaling cascade. This cascade activates a series of adaptor molecules, such as MyD88 and MAL, which promote the activation of proteins like nuclear factor kB (NF-kB) and activator protein-1 (AP-1). Thanks to the activation of NF-kB, transcription begins in the nucleus of proinflammatory cytokines such as TNF-5ØÂÞ, IL-1B, IL-6, and IL-8, which play a fundamental role in the inflammatory response [24]. This process is crucial in the modulation of inflammation, and its dysfunction is associated with several inflammatory pathologies.[24]

NF-kB is an intracellular transcription factor that plays a determining role in several biological processes,[3] Its exaggerated activation is linked to the progression of inflammation due to LPS,[3] as it participates in the regulation of the expression of proinflammatory cytokines, chemokines, adhesion molecules, and inducible enzymes (COX-2, inducible nitric oxide synthase). Furthermore, it intervenes in the control of lymphocyte proliferation and differentiation by mediating the expression of specific proteins involved in the immune response, such as the major histocompatibility complex, costimulatory molecules, and regulatory cytokines (IL-2, IL-12, and interferon).[26]

The results of inulin supplementation on inflammatory markers have been contradictory. Inulin has a limited capacity to modify the responses induced by lipopolysaccharides directly, its anti-inflammatory effect could depend on the host intestinal microbiota that is responsible for producing short-chain fatty acids.[26] Meng et al.[27] propose that the direct effect of inulin on the decrease in the expression of inflammatory factors such as NF-kB, TNF-a, and IL-6 depends on the inhibition of the NF-kB pathway.[26, 27] The difference between the two studies relies on the methodology used to obtain information.

Furthermore, in vitro studies in murine macrophages (RAW 264.7) exposed to lipopolysaccharides, through transcriptomic analysis, demonstrated that inulin-type fructans regulate gene expression and transcriptional pathways, promoting an anti-inflammatory phenotype.[26] In this study, Farabegoli et al. concluded that inulin leads to a decrease in NF-kB levels, which in turn downregulates the expression of inflammatory factors such as COX-2 and therefore reduces proinflammatory prostaglandins.[26] They also observed that the inhibition of the release of inflammatory mediators was related to the concentration of inulin used.

In parallel, Lu et al. obtained similar results in obese dogs, since they postulate that the reduction in the serum concentration of LPS, NF-kB, TNF-5ØÂÞ and IL-6 and thus the decrease in the degree of inflammation of adipose tissue, derives from the modulation of the intestinal microbiota, which in turn is dependent on the TLR/NF-kB pathway.[28]

SCFAs are known to participate in the

systemic immune response and in different stages of the inflammation process. They achieve this by inhibiting histone deacetylases (HDAC) and by activating G protein-coupled receptors (GPR), also called free fatty acid receptors (FFAR)[17] thereby inhibiting the production of cAMP.[29]

Examples are GPPR41 (FFAR3) and GPR43 (FFAR2), and GPR109 (hydrocarboxylic acid receptor 2 or HCA2),[17] which are expressed in most immune cells.[29,30] SCFAs selectively activate these receptors; acetate, propionate, and butyrate effectively activate GRP41 and GRP43 [29], while GRP109a is mainly activated by butyrate and niacin.[30]

Activation of the GPR43 receptor on neutrophils promotes the recruitment of polymorphonuclear leukocytes (PMN) to the inflammatory site.[17] Furthermore, colonic T cells induce differentiation and enhance the suppressive function of Treg cells through epigenetic proteins.[17] On the other hand, butyrate activation of the GRP109a receptor increases the production of IL-10 and Aldh-1a 17, allowing colon dendritic cells and macrophages the ability to induce the generation of Treg cells.[17]

In this sense, a study in mice with liver injury supplemented with said SCFA found a reduction in the activation of macrophages and the levels of TNF-a and IL.6.[25] In mice with hepatic steatosis there was a decrease in the expression of TLR4, MyD88 and in the serum concentrations of TNF-á, IL-1, IL-2, IL-6, and INF-a.[31]

Effects of Inulin on Inflammatory Markers in Specific Pathologies

Obesity

Obesity is a chronic disease consisting of excessive adipose tissue accumulation, this condition has a high prevalence worldwide. According to data from the WHO for the year 2022, one in eight people was obesity, and 43% of adults over 18 years old were overweight, with 16% having obesity.[32] Obesity is a multifactorial disease, with its development influenced by an obesogenic environment, psychosocial factors, and genetic variants, all of which lead to an energy imbalance between caloric intake and expenditure.[32]

Continuous inflammation is characteristic of obesity. Two decades ago, obesity and elevated TNF-5ØÂÞ levels were linked.[33] Elevated TNF-5ØÂÞ influences adipose tissue, reducing the insulin sensitivity of tissues. Mice lacking TNF-5ØÂÞ receptors or blocking these receptors show beneficial effects on tissue insulin sensitivity, decreasing resistance.[33]

Recently, a relationship has been found between obesity and alterations in the intestinal microbiota in both animal models and humans, since Liu and collaborators observed that there is an altered Firmicutes/Bacteroides relationship in this type of patient.[34] Furthermore, in an experimental study they concluded that the microbiota plays an important role in the regulation of adipose tissue because when transplanting normal microbiota to mice free of it, an increase in insulin resistance and adipose tissue was generated.[35]

LPS plays a crucial role in developing insulin resistance, diabetes, and obesity. Cani et al carried out a comparative study in mice, where the first group was administered a high-fat diet for 4 weeks with which an increase of up to threefold in LPS levels was observed after the start of the diet; while, the other group, an infusion of LPS was performed until the serum values of the first group were reached. The authors concluded that there was an increase in the production of TNF-a, IL-1, and IL-6, as well as insulin resistance.[36]

Regarding the administration of inulin, it was found that it reduces inflammation markers in both animal and human models since a significant decrease in IL-6 and C-reactive protein has been reported in a study in overweight children; in addition to less weight gain.[37]

The above is added to the fact that it increases weight loss as an adjuvant with a normocaloric diet in overweight mice[38] and that it improves intestinal barrier function accompanied by a reduction in hepatic steatosis.[39]

Inflammatory Bowel Disease

Inflammatory bowel disease (IBD) encompasses two entities known as Crohn's disease and ulcerative colitis.[3] It has been postulated that this pathology is the result of an inadequate inflammatory response of the intestinal microbiota in subjects with genetic susceptibility [40] where cells of both the innate immune system (neutrophils, macrophages, dendritic cells, etc.) and some cells of the adaptive immune system (T and B lymphocytes) participate. The activation of these cells leads to an increased local expression of markers such as TNF-á, IL-1B, and INF-ã, among others.[40] It has

been observed that the administration of inulin in mice prevents IBD symptoms and decreases serum levels of inflammatory markers such as IL-6.[41]

Diabetes

In metabolic diseases such as type 2 diabetes, alterations in the microbiota act as a "trigger" for the generation of an inflammatory response [2] conditioned largely by an increase in LPS derived from Gram-negative bacteria[3] In addition to this, a significant reduction in the protective and anti-inflammatory microbiota is also observed, a fact that further promotes the chronic inflammatory phenomenon.[3]

Meng-Ying and collaborators observed that the administration of inulin reduces the inflammatory state evidenced by the decrease in IL-1B, IL-6, and TNF-a, as a consequence of the inhibition of various inflammatory pathways, among which the IKKB/NF-KB pathway stands out.[3] Furthermore, they concluded that the protective effects of inulin in mice with diabetes can be attributed to modifications in the intestinal microbiota and changes in the concentration of short chain fatty acids derived from these.[3]

In another experimental study, the researchers administered inulin to mice at different stages of diabetes: healthy, prediabetic, and diabetic. Mice receiving inulin had reduced serum LPS, IL-6, TNF-5ØÂÞ, and IL-17 levels and exhibited reductions in fasting glucose, glycated hemoglobin, and blood lipids.[42]

Polycystic Ovary Syndrome

Polycystic ovary syndrome results from a hormonal imbalance that is expressed through ovarian dysfunction, hyperandrogenism and insulin resistance, which is also accompanied by anatomical alterations with the presence of multiple ovarian cysts.[43] It has been observed that there is a close relationship between clinical characteristics of the disease and the presence of TNF-á.[44]

Observational studies such as that of Li et al. concluded that the administration of inulin in people with this entity helps to improve sex hormone imbalances, reduces BMI, and, above all, reduces plasma concentrations of inflammation markers such as TNF-á.[45]

Depression

Evidence shows that patients with depression have alterations in their gut microbiota,[46] and dysbiosis is also associated with other mental conditions, such as neurodegenerative diseases and neurodevelopmental disorders.[46] Experimental studies in animal models demonstrate that fecal microbiota transplantation alleviates depression symptoms.[46]

Depression is the most common mental illness worldwide, with high morbidity.[46] It may be associated with inflammatory disorders, such as endotoxemia secondary to gut dysbiosis in obese patients.[47] As a result, inulin has been used as a prebiotic in various studies to observe whether it can reduce depression symptoms and inflammatory markers. In animal models, promising results have been reported, including a reduction in depressive symptoms and inflammatory markers and an increase in anti-inflammatory markers.[48]

However, studies conducted in humans have reported controversial evidence. One study in which inulin was administered for 8 weeks to women with depression reported no significant difference in depression scales, inflammation markers, intestinal permeability markers, or endotoxemia markers.[47] Another study, consisting of the administration of *Lactobacillus rhamnosus* G and inulin to patients with coronary disease and depressive symptoms, reported that supplementation with both improved anxiety and depression symptoms, as well as reduced inflammatory markers. When combined, they acted better than when used alone.[49]

As summary, table 1 shows the pathologies potentially modified by inulin.

Synergistic Effects: Symbiotic

Symbiotic are the combination of live microorganisms, also called probiotics; and substrates that are specifically used by the host's microbiota (prebiotics) and that provide benefits after consumption [50] it has been observed that the use of symbiotic has a greater effect than the use of each constituent separately.[50]

An example of this is what was found in an experimental study in rats with colitis, in which better effects were demonstrated when using inulin as a prebiotic and infantile Bifidobacterium as a probiotic in combination.[50]

DISCUSSION

Inulin is found in a wide range of plant species.[6,10,12,14] Soluble inulin is stable and has not

toxicity;[10] and it has beneficial effects on functions of colon.[7]

The microbiota degrades inulin and is fermented into SCFA,[10,11,16] and they have effects on intestinal epithelium and homeostasis of immunity.[6,10,11]

Intestinal dysbiosis is linked to inflammatory markers, resulting in expression of cytokines as TNF-á, IL-6 and IL-8, among others.[1,21] These metabolic alterations are closely linked to human diseases such as obesity, diabetes, inflammatory bowel disease, polycystic ovary syndrome, depression, among others.[3.33.45.48] The administration of inulin reduces inflammation markers in animal models and humans, decreased IL-6 and C-reactive protein and less weight gain. [37] These effects on metabolism may be beneficial to human health, and it is needed to design protocols with the objective of confirm those effects.

The use of inulin as a supplement opens many possibilities for research in humans, as support for many diseases that currently affect humans.

CONCLUSION

Interest in modulating the gut microbiota using prebiotics, probiotics, and synbiotics to treat or prevent diseases related to inflammation has increased significantly in recent times. However, most clinical trials use animal models, and few involve humans.

One prebiotic that has received particular attention is inulin, an indigestible oligosaccharide composed of linear chains of fructose with a terminal glucose molecule. In addition to acting as dietary fiber, inulin helps modify the gut microbiota population to promote a greater abundance of beneficial bacteria for the host. Other benefits of inulin are due to the effect of its metabolites, SCFAs, which are products of its degradation in various systemic and local processes. One such effect is its role in reducing inflammation markers such as TNF-5ØÂÞ, IL-1B, IL-6, and IL-17, primarily by participating in metabolic pathways associated with recognizing lipopolysaccharides or SCFAs, which involve immune system cells.

Thanks to studies, results have supported the use of inulin for reducing inflammation markers. However, there is room to unify methodologies and extrapolate results to other populations.

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Ethics statement

This review did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed consent statement

This review did not involve human participants, and therefore, informed consent was not required.

Clinical trial registration

This review does not involve any clinical trials.

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Not Applicable.

Author' contributions

Nicolás Padilla-Raygoza, design the review, wrote the first draft and the final report; Gilberto Flores-Vargas, review the first draft and participated in the final report; Omar López-Guzmán, searched in databases to obtain articles, participated in the final draft and in the final report; Yaret Valeria Rodríguez-Aguilar, searched in databases to obtain articles, participated in the final draft and in the final report; All authors approved the final version

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