

TITLE

COMPOSITIONS AND METHODS FOR IMPROVING IMMUNE HEALTH

TECHNICAL FIELD

[0001] The present disclosure generally relates to compositions and methods for improving immune health. Some embodiments are directed to a composition comprising milk protein and further comprising a mixture of lactose, glucose, galactose and galactooligosaccharide (GOS).

BACKGROUND

[0002] Gut microbiota metabolites play an important role in host health and nutrient metabolism. More and more scientific evidence suggest that metabolites produced by gut microbiota are important mediators of benefits for the host. Supplementation with galactooligosaccharides (GOS) has been previously linked to several health benefits, predominantly via gut microbiome modulation. While many studies are focused on beneficial metabolites originating from gut carbohydrate fermentation, it appears that bacterial metabolites from protein metabolisms also play an important role in host physiology.

[0003] There remains a need for a composition for easy and convenient administration to an individual resulting in an increase in beneficial microbial metabolites.

SUMMARY

[0004] Embodiments of the disclosure concern methods and/or compositions for improving immune health, in which reduced blood or intracellular levels of certain metabolites, and the fecal level of certain bacteria are directly or indirectly related affected. In specific embodiments, the level of certain metabolites, and corresponding level of certain bacteria such as Bifidobacteria, in an individual is increased, upon which a medical condition or physical state is thereby treated, prevented, or had a delay in onset. In certain embodiments, the level of certain metabolites in an individual is reduced, upon which a medical condition or physical state is thereby treated, prevented, or has a delay in onset.

[0005] In particular embodiments, a method for improving immune health includes administering to an individual in need thereof a low sugar, low lactose, milk-based composition comprising galactooligosaccharide. In some embodiments, the composition comprises milk protein, preferably at 20-40 % by dry weight of the composition; and a mixture of lactose,

glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% or 32-55%, by dry weight of the composition; preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[0006] The improving of the immune health can comprise at least one result selected from the group consisting of: (a) protection from infections, such as viral respiratory infections; (b) protection against pathogens; (c) reducing inflammation; (d) preventing and/or attenuating oxidative stress; (e) improving intestinal barrier; (f) reducing intestinal permeability; (g) promoting growth of *Bifidobacterium*; (h) increasing *Bifidobacterium* shunt pathway; (i) increasing NAD salvage pathway; and (j) preventing and/or treating allergic asthma, (k) promoting immune homeostasis; (l) preventing and/or treating clostridium difficile infection, (m) cancer immunotherapy; (o) preventing and/or treating autoimmune diseases; combinations thereof.

[0007] The composition may further comprise 0.5-30% by dry weight of at least one of milk fat or mineral derived from milk, preferably a combination thereof. The composition may further comprise 5-20% by dry weight of vegetable oil.

[0008] Preferably the composition is administered in an amount effective to increase one or more metabolite levels selected from the group consisting of: 3-indole propionate, propionate, valerate, Indole-3- carboxylate, N,N-Dimethylglycine, tricarballic acid, acetate, caprylic acid, nicotinamide, beta-alanine, ketone bodies, 3-hydroxybutyrate, 12,13-diHODE, and/or 3-hydroxydecanoic acid. Preferably, the composition is administered in an effective amount to increase one or more *Bifidobacterium*, including but not limited to *B. longum*, *B. adolescentis*, *B. bifidum*.

[0009] Another aspect of the present disclosure is a method for preventing oxidative stress, reducing inflammation, improving the intestinal barrier, and/or reducing intestinal permeability, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of 3-indole propionate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-indole propionate in an individual.

[0010] Yet another aspect of the present disclosure is a method for treating viral respiratory infections, such as respiratory syncytial virus (RSV), the method comprising administering to an individual in need thereof or at risk thereof any of the compositions

disclosed herein. The composition may be administered in an amount effective for increasing levels of acetate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of acetate in an individual.

[0011] Yet another aspect of the present disclosure is a method for one or more of preventing and/or treating viral respiratory infections, such as respiratory syncytial virus (RSV) and/or protecting an individual against pathogens, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of *Bifidobacterium* in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of *Bifidobacterium* in an individual.

[0012] Yet another aspect of the present disclosure is a method for reducing and/or preventing oxidative stress, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of 3-hydroxybutyrate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-hydroxybutyrate in an individual.

[0013] The embodiments disclosed herein each include one or more advantageous features not provided by the compositions and methods of “Methods of Use of Oligosaccharide Compositions For Modulating Microbiota And Their Metabolic Products, And As Therapeutics For Health Application,” International Patent Publication No. WO2022241163, by Amicucci et al.; “Process For Preparing Enzymatically-Treated Food Compositions With Gos And Low Lactose Content And Food Compositions Thereof,” International Patent Publication No. WO2023057540, by Sabine et al.; “Milk Oligosaccharide Galactooligosaccharide Composition For Infant Formula Containing The Soluble Oligosaccharide Fraction Present In Milk, And Having A Low Level Of Monosaccharides, And A Process To Produce The Composition,” U.S. Patent Publication No. 20140087021, by Berrocal Rafael et al.; “Synthetic composition for treating metabolic disorders,” U.S. Patent No. 11,529,364, by Elison et al.; “Immune system stimulating nutrition,” U.S. Patent No. 10,124,016, by Potappel-Van’T Land Belinda et al.; “Milk products comprising high amounts of galactooligosaccharides (gos) and their production,” European Patent No. 3624594, by Tams J. W.; and “Enzymatic conversion of milk lactose to prebiotic galactooligosaccharides to produce low lactose yogurt,” by Raza,

Iqbal, Ullah, Khan, and Imran in *J Food Process Preserv.* 2018; 42:e13586. <https://doi.org/10.1111/jfpp.13586>.

[0014] Additional features and advantages are described herein and will be apparent from the following Figures and Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** shows plasma 3-indole propionate levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0016] **FIG. 2** shows plasma 3-hydroxydecanoic acid levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0017] **FIG. 3** shows plasma 12,13-DiHODE levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0018] **FIG. 4** shows plasma indoxyl sulfate levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0019] **FIG. 5** shows plasma p-cresol sulfate levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0020] **FIG. 6** shows plasma acetate levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0021] **FIG. 7** shows plasma caprylic acid levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0022] **FIG. 8** shows plasma nicotinamide levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0023] **FIG. 9** shows plasma beta-alanine levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0024] FIG. 10 shows plasma ketone body levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0025] FIG. 11 shows fecal *Bifidobacterium* levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0026] FIG. 12 shows fecal *B. longum* levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0027] FIG. 13 shows fecal *B. adolescentis* levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0028] FIG. 14 shows fecal *B. bifidum* levels after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0029] FIG. 15 shows the *Bifidobacterium* shunt pathway abundance after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0030] FIG. 16 shows the NAD salvage pathway abundance after administration of the composition disclosed herein (IP) compared to administration of a control product (CP) of lactose-free skimmed milk.

[0031] FIG. 17-21 show the increase of certain metabolites during fermentation of the composition of the present invention compared to GOS alone and a control.

DETAILED DESCRIPTION

[0032] Definitions

[0033] Some definitions are provided hereafter. Nevertheless, definitions may be located in the “Embodiments” section below, and the above header “Definitions” does not mean that such disclosures in the “Embodiments” section are not definitions.

[0034] All percentages expressed herein are by weight of the total weight of the composition unless expressed otherwise. As used herein, “about,” “approximately” and

“substantially” are understood to refer to numbers in a range of numerals, for example the range of -10% to +10% of the referenced number, preferably -5% to +5% of the referenced number, more preferably -1% to +1% of the referenced number, most preferably -0.1% to +0.1% of the referenced number. All numerical ranges herein should be understood to include all integers, whole or fractions, within the range. Moreover, these numerical ranges should be construed as providing support for a claim directed to any number or subset of numbers in that range. For example, a disclosure of from 1 to 10 should be construed as supporting a range of from 1 to 8, from 3 to 7, from 1 to 9, from 3.6 to 4.6, from 3.5 to 9.9, and so forth.

[0035] As used in this disclosure and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a protein” or “the protein” includes two or more proteins.

[0036] The words “comprise,” “comprises” and “comprising” are to be interpreted inclusively rather than exclusively. Likewise, the terms “include,” “including” and “or” should all be construed to be inclusive, unless such a construction is clearly prohibited from the context. Nevertheless, the compositions and methods disclosed herein may lack any element that is not specifically disclosed herein. Thus, a disclosure of an embodiment using the term “comprising” includes a disclosure of embodiments “consisting essentially of” and “consisting of” the components or steps identified.

[0037] The terms “at least one of” and “and/or” used respectively in the context of “at least one of X and Y” and “X and/or Y” should be interpreted as “X without Y,” or “Y without X,” or “both X and Y.” Where used herein, the terms “example” and “such as,” particularly when followed by a listing of terms, are merely exemplary and illustrative and should not be deemed to be exclusive or comprehensive.

[0038] As used herein, “related to,” “associated with” and “linked with” mean occurring concurrently, preferably mean caused by the same underlying condition, more preferably mean that one of the identified conditions is at least indirectly caused by the other identified condition, and most preferably mean that one of the identified conditions is directly caused by the other identified condition.

[0039] The term “chronic kidney disease” refers to a gradual loss of kidney function. Kidneys filter wastes and excess fluids from the blood, which are then removed in the urine. Advanced chronic kidney disease can cause dangerous levels of fluid, electrolytes and wastes to build up in the body. Chronic kidney disease occurs when a disease or condition impairs kidney function, causing kidney damage to worsen over several months or years. Diabetes and high blood pressure are two main risk factors.

[0040] The term “diabetes” shall refer to a disease that results in high glucose levels in the bloodstream.

[0041] “Cognitive function” may be defined as the mental process of knowing, including aspects such as awareness, perception, reasoning, and judgment, including but not limited to that which comes to be known, as through perception, reasoning, or intuition; knowledge. In specific embodiments, compositions as contemplated herein are provided to an individual to improve memory, including in an individual with normal or impaired memory.

[0042] The terms “food”, “food supplement”, “food product” and “food composition” mean a product or composition that is intended for ingestion by an individual such as a human and provides at least one nutrient to the individual. The compositions of the present disclosure, including the many embodiments described herein, can comprise, consist of, or consist essentially of the elements disclosed herein, as well as any additional or optional ingredients, components, or elements described herein or otherwise useful in a diet supplement.

[0043] “Prevention” includes reduction of risk, incidence and/or severity of a condition or disorder. The terms “treatment” and “treat” include both prophylactic or preventive treatment (that prevent and/or slow the development of a targeted pathologic condition or disorder) and curative, therapeutic or disease-modifying treatment, including therapeutic measures that cure, slow down, lessen symptoms of, and/or halt progression of a diagnosed pathologic condition or disorder; and treatment of patients at risk of contracting a disease or suspected to have contracted a disease, as well as patients who are ill or have been diagnosed as suffering from a disease or medical condition. The terms “treatment” and “treat” do not necessarily imply that a subject is treated until total recovery. The terms “treatment” and “treat” also refer to the maintenance and/or promotion of health in an individual not suffering from a disease but who may be susceptible to the development of an unhealthy condition. The terms “treatment” and “treat” are also intended to include the potentiation or otherwise enhancement of one or more primary prophylactic or therapeutic measures. As non-limiting examples, a treatment can be performed by a patient, a caregiver, a doctor, a nurse, or another healthcare professional.

[0044] As used herein, the term “low lactose” shall refer to a composition with less than or equal to 30% of lactose.

[0045] As used herein, the term “low sugar” shall refer to a composition with less than or equal to 55% of the composition.

[0046] As used herein, a prophylactically or therapeutically “effective amount” is an amount that prevents a deficiency, treats a disease or medical condition in an individual, or,

more generally, reduces symptoms, manages progression of the disease, or provides a nutritional, physiological, or medical benefit to the individual.

[0047] As used herein, the term “metabolic health” shall refer to the ability for your body to digest and absorb nutrients from food without abnormal or unhealthy spikes in blood sugar, blood lipid, inflammation, and/or insulin. “Improving metabolic health” shall refer to mechanisms for directly or indirectly reducing the incidence of spikes in blood sugar, inflammation, insulin, and/or blood fat. Additionally, “improving metabolic health” may refer to preventing and/or treating obesity, type II diabetes, heart disease, cognitive function, stroke, kidney disease, and/or fatty liver disease.

[0048] As used herein, the term “oxidative stress” refers to the state in an individual, or cell or tissue of an individual, of an imbalance between the production of reactive oxygen and the ability to detoxify the reactive intermediates or easily repair the resulting damage in a biological system. The natural reducing environment within cells is maintained by processes using a constant input of metabolic energy, and disturbances in this normal redox state can result in toxic effects through the production of, for example, free radicals and peroxides that damage cellular components, such as proteins, lipids, and/or DNA, for example.

[0049] The term “composition” may mean a food, beverage, dietary supplement, complete nutrition or oral nutritional supplement (ONS) or medical food composition, or mixture thereof.

[0050] The composition can be in solid form (e.g., powder) or in liquid form. The amount of the various ingredients can be expressed in g/100 g of the composition on a dry weight basis when it is in a solid form, e.g. a powder, or as a concentration in g/100 mL of the composition when it refers to a liquid form (this latter also encompasses liquid composition that may be obtained from a powder after reconstitution in a liquid such as water.)

[0051] The term “unit dosage form,” as used herein, refers to physically discrete units suitable as unitary dosages for human and animal subjects, each unit containing a predetermined quantity of the composition disclosed herein in an amount sufficient to produce the desired effect, in association with an acceptable diluent, carrier or vehicle. The specifications for the unit dosage form depend on the particular compounds employed, the effect to be achieved, and the pharmacodynamics associated with each compound in the host.

[0052] Embodiments

In an aspect of the present disclosure, a method of improving immune health comprises administering to an individual in need thereof or at risk thereof a low sugar, low lactose, milk-based composition comprising galactooligosaccharide.

[0053] In some embodiments, the composition comprises 20-40 % by dry weight of milk protein; and 32-55% by dry weight of a mixture of lactose, glucose, galactose and galactooligosaccharide.

[0054] In some embodiments, the composition comprises 35-55% by dry weight of a mixture of lactose, glucose, galactose and galactooligosaccharide.

[0055] In an embodiment, the mixture of lactose, glucose and galactose and galactooligosaccharide comprises: 0.1-30% by weight of lactose.

[0056] In an embodiment, the mixture of lactose, glucose and galactose and galactooligosaccharide comprises: 8-40% by weight of glucose.

[0057] In an embodiment, the mixture of lactose, glucose and galactose and galactooligosaccharide comprises: 0.1-20% by weight of galactose.

[0058] In an embodiment, the mixture of lactose, glucose and galactose and galactooligosaccharide comprises 40-90% by weight of galactooligosaccharide.

In an embodiment, the milk-based composition comprises:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 32-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[0059] In another embodiments, the milk-based composition comprises:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[0060] Some embodiments provide a contribution from each of the components of the composition individually, in combination, and/or synergistically.

[0061] In certain embodiments of the invention, there are methods and compositions for improving immune health, the improvement of immune health caused directly or indirectly by increasing or decreasing levels of certain metabolites or certain bacteria such as Bifidobacteria in the individual. The individual may be of any age or state of health, although in particular embodiments the individual may be susceptible to particular medical conditions

or physical states that are treated or prevented directly or indirectly with increased or decreased metabolite levels, or has a medical condition or physical state that are treated or prevented directly or indirectly with increased metabolite levels. The compositions delivered to the individual in such cases include at least a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture comprising: 0.1-30% by weight of lactose, 8-40% by weight of glucose, 0.1-20% by weight of galactose and 40-90% by weight of galactooligosaccharide, in particular to facilitate raising or lowering specific metabolite levels in the individual. One can measure specific metabolite levels through plasma or fecal samples, for example, in methods well known in the art.

[0062] In specific embodiments, improvement of immune health is associated with increased and/or decreased levels of certain metabolites, certain bacteria such as *Bifidobacteria*, or functional derivatives thereof. In particular embodiments, improving immune health comprises one or more of the following: (a) protection from infections, such as viral respiratory infections; (b) protection against pathogens; (c) reducing inflammation; (d) preventing and/or attenuating oxidative stress; (e) improving intestinal barrier; (f) reducing intestinal permeability; (g) promoting growth of *Bifidobacterium*; (h) increasing *Bifidobacterium* shunt pathway; (i) increasing NAD salvage pathway; and (j) preventing and/or treating allergic asthma, (k) promoting immune homeostasis; (l) preventing and/or treating *Clostridium difficile* infection, (m) cancer immunotherapy, (o) preventing and/or treating autoimmune diseases; combinations thereof. The individual may be diagnosed with such condition(s) or may be suspected of having such condition(s) or may be susceptible to such condition(s). The individual may be treated with other therapy or therapies in addition to methods of the disclosure.

[0063] In one embodiment of the disclosure, there is a method of producing increased blood levels of certain metabolites, including 3-indole propionate, acetate, caprylic acid, nicotinamide, beta-alanine, ketone bodies, 3-hydroxybutyrate, 12,13-diHODE, propionate, indole-3-carboxylate, valerate, N,N-Dimethylglycine, tricarballylic acid, propionate, and/or 3-hydroxydecanoic acid (or functional derivatives thereof) or increased fecal levels of *Bifidobacterium*, including but not limited to *B. adolescentis*, *bifidum*, *longum*, in an individual in need thereof by administering the composition disclosed herein. The individual may be known to have a medical condition or physical state that would benefit from increased metabolite levels, or the individual may be suspected of having a medical condition or physical state that would benefit from increased metabolite levels, or increased beneficial fecal bacteria levels.

[0064] The method may comprise identifying the individual as having a medical condition or physical state that would benefit from increased metabolite levels, or increased beneficial fecal bacteria levels, and/or the method may comprise identifying the individual as at risk of a medical condition or physical state that would benefit from increased metabolite levels, or increased beneficial fecal bacteria levels. In particular embodiments, the individual subjected with methods and/or compositions of the invention is desiring prevention of one or more undesirable physical states (or the effects thereof, such as with aging) or medical conditions.

[0065] In specific embodiments, an individual is provided effective amounts of compositions as described herein for the explicit purpose of raising intracellular levels of 3-indole propionate, acetate, caprylic acid, nicotinamide, beta-alanine, ketone bodies, 3-hydroxybutyrate, 12,13-diHODE, propionate, indole-3-carboxylate, valerate, N,N-Dimethylglycine, tricarballic acid, propionate, and/or 3-hydroxydecanoic acid or increasing fecal levels of *Bifidobacterium*, including but not limited to *B. adolescentis*, *bifidum*, *longum*, because it is determined that the individual is afflicted with a condition for which such levels are directly or indirectly related. Additionally, an individual is provided effective amounts of compositions as described herein for the explicit purpose of decreasing levels of indoxyl sulfate and/or p-cresol sulfate because it is determined that the individual is afflicted with a condition for which such levels are directly or indirectly related.

[0066] In some embodiments, there is a method of reducing and/or preventing oxidative stress in an individual. In a specific embodiment, the methods are useful for treating and/or preventing medical conditions associated with oxidative stress. In particular cases, the present invention provides methods and compositions useful for aging. In specific embodiments, administering the compositions contemplated herein increase levels of 3-hydroxybutyrate for which oxidative stress and age-associated diseases are directly or indirectly related.

[0067] In some embodiments, the composition comprises 20-40% by dry weight of milk protein. Milk protein includes any protein or combination of proteins derived from milk. The milk proteins may have been derived from milk in any suitable way. In a preferred embodiment, the composition comprises 25-40%, more preferably 30-40% by dry weight of milk protein.

[0068] In some embodiments, the food ingredient further comprises 35-55%, more preferably 32-55%, by dry weight of a mixture of lactose, glucose, galactose and GOS, the mixture comprising: 0.1-30% by weight of lactose, 8-40% by weight of glucose, 0.1-20% by

weight of galactose and 40-90% by weight of GOS. In a preferred embodiment, the food ingredient comprises 45-55% by dry weight of the mixture of lactose, glucose, galactose and GOS; in a more preferred embodiment, the food ingredient comprises 50-55% by dry weight of the mixture of lactose, glucose, galactose and GOS. In another preferred embodiment of the invention, the mixture of lactose, glucose, galactose and GOS comprises 60-90% by weight of GOS, more preferred 70-90% by weight of GOS. In yet another preferred embodiment, the mixture of lactose, glucose, galactose and GOS contains: 1-20% by weight of lactose, 15-35% by weight of glucose, 1-10% by weight of galactose and 50-85% by weight of GOS. In a more preferred embodiment of the invention, the mixture of lactose, glucose, galactose and GOS contains: 1-14% by weight of lactose, 15-29% by weight of glucose, 1-8% by weight of galactose and 70-90% by weight of GOS.

[0069] In some embodiments, the mixture of lactose, glucose, galactose and GOS comprises 0.1-30%, such as 0.1-5%, 5-10%, 10-15%, 15-20%, 20-25%, or 25-30% by weight of lactose. In some embodiments, the mixture of lactose, glucose, galactose and GOS comprises 8-40%, such as 8-16%, 16-24%, 24-32%, or 32-40%, by weight of glucose. In some embodiments, the mixture of lactose, glucose, galactose and GOS comprises 0.1-20%, such as 0.1-5%, 5-10%, 10-15%, or 15-20%, by weight of galactose. In some embodiments, the mixture of lactose, glucose, galactose and GOS comprises 40-90%, such as 40-50%, 50-60%, 60-70%, or 70-80% by weight of GOS.

[0070] The composition may further comprise 0.5-30% by dry weight of milk fat and/or minerals derived from milk, preferably 2-20%, more preferably 6-10% by dry weight of milk fat and/or minerals derived from milk. Milk fat includes fat derived from milk in any suitable way. Milk derived minerals include minerals derived from milk in any suitable way, e.g. calcium, sodium, potassium, phosphorus and/or magnesium salts. Milk fat and/or milk derived minerals may originate from liquid milk, such as skim milk, partially skimmed milk and/or whole milk, or from milk powder, such as e.g. skim milk powder and/or whole milk powder.

[0071] In a preferred embodiment, the composition further comprises 5-20% by dry weight of vegetable oil, more preferably 8-15% by dry weight of vegetable oil. The vegetable oil may be any suitable vegetable oil, preferably palm oil. In one embodiment, the composition relates to a cocoa, coffee, fruit based and/or malt beverage powder comprising: 10-35% by weight of non-fat milk solids; 0-65% by weight of malt extract solids; 0-15% by weight of cocoa solids; 6-15% by weight of vegetable oil and/or milk fat; 0-25% by weight of sucrose; 1-6% by weight of glucose; 0.1-5% by weight of lactose; and 3-10% by weight of GOS.

[0072] Non-fat milk solids may be derived from any suitable milk source, such as e.g. liquid milk, e.g. skim milk and/or whole milk, and/or milk powder, e.g. skim milk powder and/or whole milk powder. If liquid milk is used, it may be concentrated, e.g. by evaporation or filtration. Malt extract solids may be in any suitable form, e.g. in the form of a powdered or liquid extract of malted barley and/or wheat. Cocoa solids may be from any suitable cocoa source, e.g. in the form of cocoa powder, cocoa mass and/or cocoa butter. Vegetable oil may be any suitable vegetable oil, preferably palm oil. Milk fat may be derived from any suitable milk source, such as e.g. liquid milk or cream, e.g. skim milk, cream, and/or whole milk, and/or milk powder, e.g. skim milk powder, cream powder, and/or whole milk powder, and/or may be in the form of butter, butter oil and/or anhydrous milk fat. If liquid milk or cream is used, it may be concentrated, e.g. by evaporation or filtration.

[0073] Glucose, lactose and GOS are preferably derived from the composition of the present invention. A cocoa and/or malt beverage powder of the invention preferably comprises 10-30% by dry weight of the composition of the invention, more preferably 15-25% by dry weight of the composition of the invention. In a preferred embodiment of the invention, the cocoa and/or malt beverage powder comprises 2-4% by weight of glucose; 0.1-2% by weight of lactose; and 5-10% by weight of GOS.

[0074] A cocoa and/or malt beverage powder of the invention may comprise sucrose. Due to the amounts of lactose, glucose and GOS present in the product, the amount of sucrose may be reduced as compared to a conventional cocoa and/or malt beverage powder while retaining an acceptable taste, sweetness and texture. In a preferred embodiment, a cocoa and/or malt beverage product of the invention does not comprise sucrose. In another preferred embodiment, a cocoa and/or malt beverage powder of the invention comprises 1-25% by weight of sucrose, more preferably 5-20% by weight of sucrose.

[0075] A cocoa and/or malt beverage powder of the invention may comprise any other suitable ingredients known in the art, such as e.g. vitamins, minerals, buffer salts, emulsifiers and stabilizers.

[0076] A cocoa and/or malt beverage powder of the invention may be produced by any suitable method known in the art. The ingredients may e.g. be in powder form and mixed in the dry state, some or all ingredients may be mixed in aqueous solution/suspension and subsequently dried to a powder, or some or all powdered ingredients may e.g. be co-agglomerated to produce a powder with improved solubility.

[0077] In a preferred embodiment, the invention relates to a cocoa and malt beverage powder comprising 15-35% by weight of non-fat milk solids; 20-50% by weight of

malt extract solids; 5-15% by weight of cocoa solids; 6-15% by weight of vegetable oil and/or milk fat; 0-25% by weight of sucrose; 1-6% by weight of glucose; 0.1-5% by weight of lactose; and 3-10% by weight of galactooligosaccharide.

[0078] In one embodiment, the composition relates to a liquid cocoa and/or malt beverage product comprising: 3-10% by weight of non-fat milk solids; 1-6% by weight of malt extract solids; 0-5% by weight of cocoa solids; 0.3-5% by weight of vegetable oil and/or milk fat; 0-5% by weight of sucrose; 0.4-1.5% by weight of glucose; 0.01-1% by weight of lactose; and 0.5-5% by weight of GOS.

[0079] A liquid cocoa and/or malt beverage product is a cocoa and/or malt beverage product in liquid form which is suitable to be consumed without addition of liquid. It may e.g. be packed in a container from which it can be consumed directly upon opening.

[0080] Non-fat milk solids may be derived from any suitable milk source, such as e.g. liquid milk, e.g. skim milk and/or whole milk, and/or milk powder, e.g. skim milk powder and/or whole milk powder. If liquid milk is used, it may be concentrated, e.g. by evaporation or filtration. Malt extract solids may be in any suitable form, e.g. in the form of a powdered or liquid extract of malted barley and/or wheat. Cocoa solids may be from any suitable cocoa source, e.g. in the form of cocoa powder, cocoa mass and/or cocoa butter. Vegetable oil may be any suitable vegetable oil, preferably palm oil. Milk fat may be derived from any suitable milk source, such as e.g. liquid milk or cream, e.g. skim milk, cream, and/or whole milk, and/or milk powder, e.g. skim milk powder, cream powder, and/or whole milk powder, and/or may be in the form of butter, butter oil and/or anhydrous milk fat. If liquid milk or cream is used, it may be concentrated, e.g. by evaporation or filtration.

[0081] Glucose, lactose and GOS are preferably derived from the composition of the present invention. A liquid cocoa and/or malt beverage product of the invention preferably comprises 10-30% by dry weight of the composition of the invention, more preferably 15-25% by dry weight. In a preferred embodiment, the liquid cocoa and/or malt beverage product comprises 0.5-1% by weight of glucose; 0.01-0.5% by weight of lactose; and 1-4% by weight of GOS.

[0082] A liquid cocoa and/or malt beverage product of the invention may comprise sucrose. Due to the amounts of lactose, glucose and GOS present in the product, the amount of sucrose may be reduced as compared to a conventional cocoa and/or malt beverage powder while retaining an acceptable taste, sweetness and texture. In a preferred embodiment, a cocoa and/or malt beverage product of the invention does not comprise sucrose. In another preferred

embodiment, a cocoa and/or malt beverage powder of the invention comprises 0.1-5% by weight of sucrose, more preferably 1-3% by weight of sucrose.

[0083] A liquid cocoa and/or malt beverage product of the invention may comprise any other suitable ingredients known in the art, such as e.g. vitamins, minerals, buffer salts, emulsifiers and stabilizers.

[0084] A liquid cocoa and/or malt beverage product of the invention may be produced in any suitable way known in the art. The ingredients may be in liquid and/or powdered form and may be mixed into an aqueous solution/suspension, e.g. with the addition of water to achieve the desired concentration of ingredients. A food ingredient of the invention is preferably added in liquid form, but may also be added in powdered form.

[0085] In a preferred embodiment, the composition relates to a liquid cocoa and/or malt beverage product comprising: 3-10% by weight of non-fat milk solids; 1-6% by weight of malt extract solids; 1-5% by weight of cocoa solids; 0.3-5% by weight of vegetable oil and/or milk fat; 0-5% by weight of sucrose; 0.4-1.5% by weight of glucose; 0.01-1% by weight of lactose; and 0.5-5% by weight of GOS.

[0086] The composition can be in any oral nutritional form, e.g., as a health drink, as a ready-made drink, optionally as a soft drink, including juices, coffee, tea, milk-shake, yogurt drink, smoothie or soy-based drink; in a food bar; a powder, such as in sachet form; or dispersed in foods of any sort, such as baked products, cereal bars, dairy bars, snack-foods, soups, breakfast cereals, muesli, candies, tabs, cookies, biscuits, crackers (such as rice crackers), and dairy and plant-based products.

[0087] In some embodiments, the composition relates to a ready to drink beverage. The % weight are based on dry matter of the composition before reconstitution. In an embodiment, the ready to drink beverage comprises 32%-55% of a mixture of Lactose, Glucose, Galactose, and GOS. In an embodiment, the composition comprises 40-45% by dry weight of the mixture of lactose, glucose, galactose and GOS. In an embodiment, the composition comprises 45-50% by dry weight of the mixture of lactose, glucose, galactose and GOS. In an embodiment, the food ingredient comprises 32-37% by dry weight of the mixture of lactose, glucose, galactose and GOS.

[0088] In some embodiments, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 1-25% by weight of lactose, such as 1-5%, 5-10%, 10-15%, 15-20%, or 20-25% by weight of lactose. In some embodiments, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 15-35% by weight of glucose, such as 15-20%, 20-25%, 25-30%, or 30-35% by weight of glucose. In some embodiments, the mixture of

Lactose, Glucose, Galactose and GOS in the composition contains 1-10% by weight of galactose, such as 1-2%, 2-4%, 4-6%, 6-8%, or 8-10% by weight of galactose. In some embodiments, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 50-85% by weight of GOS, such as 50-60%, 60-70%, 70-80%, or 80-85% by weight of GOS.

[0089] In a preferred embodiment, the composition comprises 40-45% of a mixture of Lactose, Glucose, Galactose and GOS. In a preferred embodiment, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 10-20% by weight of lactose. In a preferred embodiment, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 15-25% by weight of glucose. In a preferred embodiment, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 0.1-5% by weight of galactose. In a preferred embodiment, the mixture of Lactose, Glucose, Galactose and GOS in the composition contains 57-70% by weight of GOS.

[0090] In some embodiments, the ready to drink beverage includes milk. In some embodiments, the milk includes full milk, skim milk, and other types of milk. In some embodiments, the ready to drink beverage is optionally fortified with one or more vitamins and minerals. In a preferred embodiment, the one or more vitamins include vitamins for providing a benefit, such as improving immunity and/or mobility.

[0091] The composition can be administered to the individual at least two days per week, at least three days per week, all seven days of the week respecting serving size; for at least one week, at least one month, at least two months, at least three months, at least six months, or even longer. In some embodiments, the composition is administered to the individual consecutively for a number of days. In an embodiment, the composition can be administered to the individual daily for at least 30, 60 or 90 consecutive days.

[0092] In some embodiments, the serving size of the composition is an amount effective to increase certain metabolites or certain bacteria such as Bifidobacteria, for example, about 100 ml, about 200 ml, or about 300 ml of the composition. In some embodiments, the composition is administered in a unit dosage form that comprises an amount of the composition effective for increasing or decreasing certain metabolites and improving metabolic health.

[0093] In view of the disclosures herein, an embodiment is a method for improving immune health, the method comprising administering to an individual in need thereof a low sugar, low lactose, milk-based composition comprising galactooligosaccharide. In some embodiments, the composition comprises milk protein, preferably at 20-40 % by dry weight of the composition; and a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition; preferably, the mixture

comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[0094] The improving of the immune health health can comprise at least one result selected from the group consisting of: (a) protection from infections, such as viral respiratory infections; (b) protection against pathogens; (c) reducing inflammation; (d) preventing and/or attenuating oxidative stress; (e) improving intestinal barrier; (f) reducing intestinal permeability; (g) promoting growth of *Bifidobacterium*; (h) increasing *Bifidobacterium* shunt pathway; (i) increasing NAD salvage pathway; and (j) preventing and/or treating allergic asthma, (k) promoting immune homeostasis; (l) preventing and/or treating clostridium difficile infection, (m) cancer immunotherapy; (n) preventing and/or treating intestinal inflammation; (o) preventing and/or treating autoimmune diseases; combinations thereof.

[0095] The composition may further comprise 0.5-30% by dry weight of at least one of milk fat or mineral derived from milk, preferably a combination thereof. The composition may further comprise 5-20% by dry weight of vegetable oil.

[0096] Preferably the composition is administered in an amount effective to increase one or more metabolite levels selected from the group consisting of: 3-indole propionate, acetate, caprylic acid, nicotinamide, beta-alanine, ketone bodies, 3-hydroxybutyrate, 12,13-diHODE, indole-3-carboxylate, propionate, valerate, N,N-Dimethylglycine, tricarballic acid, and/or 3-hydroxydecanoic acid. Preferably, the composition is administered in an effective amount to increase one or more *Bifidobacterium*, including but not limited to *B. longum*, *B. adolescentis*, *B. bifidum*.

[0097] Another aspect of the present disclosure is a method for preventing and/or treating allergic asthma, preventing and/or treating autoimmune diseases, promoting immune homeostasis, preventing oxidative stress, reducing inflammation, improving the intestinal barrier, and/or reducing intestinal permeability, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of 3-indole propionate or propionate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-indole propionate or propionate in an individual. Research has shown that increasing propionate levels has been linked to the listed benefits (See Trompette A, Gollwitzer ES, Yadava K, Sichelstiel AK, Sprenger N, Ngom-Bru C, et al. Gut microbiota metabolism of dietary fiber influences allergic airway disease and hematopoiesis. Nat Med (2014) 20(2):159–66. doi: 10.1038/nm.3444; Zaiatz-Bittencourt V,

Jones F, Tosetto M, Scaife C, Cagney G, Jones E, Doherty GA, Ryan EJ. Butyrate limits human natural killer cell effector function. *Sci Rep.* 2023 Feb 15;13(1):2715. doi: 10.1038/s41598-023-29731-5. PMID: 36792800; PMCID: PMC9932090.; Duscha A, Gisevius B, Hirschberg S, Yissachar N, Stangl GI, Dawin E, Bader V, Haase S, Kaisler J, David C, Schneider R, Troisi R, Zent D, Hegelmaier T, Dokalis N, Gerstein S, Del Mare-Roumani S, Amidror S, Staszewski O, Poschmann G, Stühler K, Hirche F, Balogh A, Kempa S, Träger P, Zaiss MM, Holm JB, Massa MG, Nielsen HB, Faissner A, Lukas C, Gatermann SG, Scholz M, Przuntek H, Prinz M, Forslund SK, Winkelhofer KF, Müller DN, Linker RA, Gold R, Haghikia A. Propionic Acid Shapes the Multiple Sclerosis Disease Course by an Immunomodulatory Mechanism. *Cell.* 2020 Mar 19;180(6):1067-1080.e16. doi: 10.1016/j.cell.2020.02.035. Epub 2020 Mar 10. PMID: 32160527.; Vinolo MA, Rodrigues HG, Nachbar RT, Curi R. Regulation of inflammation by short chain fatty acids. *Nutrients.* 2011;3:858–76: <https://www.mdpi.com/2072-6643/3/10/858>; Mills, S. W., Montgomery, S. H., & Morck, D. W. (2006). Evaluation of the effects of short-chain fatty acids and extracellular pH on bovine neutrophil function in vitro. *American Journal of Veterinary Research*, 67(11), 1901-1907.; Sina, C.; Gavrilova, O.; Forster, M.; Till, A.; Derer, S.; Hildebrand, F.; Raabe, B.; Chalaris, A.; Scheller, J.; Rehmann, A.; et al. G protein-coupled receptor 43 is essential for neutrophil recruitment during intestinal inflammation. *J. Immunol.* 2009, 183, 7514–7522.; Arpaia, N. et al. Metabolites produced by commensal bacteria promote peripheral regulatory T cell generation. *Nature* 504, 451–455 (2013)., the entireties of each of which are incorporated herein by reference.)

[0098] Yet another aspect of the present disclosure is a method for treating viral respiratory infections, such as respiratory syncytial virus (RSV), the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of acetate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of acetate in an individual.

[0099] Yet another aspect of the present disclosure is a method for one or more of preventing and/or treating viral respiratory infections, such as respiratory syncytial virus (RSV) and/or protecting an individual against pathogens, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of *Bifidobacterium* in the individual. The composition may be administered to the individual in

a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of *Bifidobacterium* in an individual.

[00100] Yet another aspect of the present disclosure is a method for reducing and/or preventing oxidative stress, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of 3-hydroxybutyrate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-hydroxybutyrate in an individual.

[00101] Yet another aspect of the present disclosure is a method for promoting immune homeostasis, preventing and/or treating clostridium difficile infection, cancer immunotherapy; preventing and/or treating intestinal inflammation; preventing and/or treating autoimmune diseases, and reducing inflammation, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of valerate in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of valerate in an individual. Research has shown that increasing valerate levels has been linked to the listed benefits (See Smith PM, Howitt MR, Panikov N, Michaud M, Gallini CA, Bohlooly YM, et al. The microbial metabolites, short-chain fatty acids, regulate colonic treg cell homeostasis. *Sci* (New York NY) (2013) 341(6145):569–73. doi: 10.1126/science.1241165, McDonald, J. A. K., Mullish, B. H., Pechlivanis, A., Liu, Z. G., Brignardello, J., Kao, D., et al. (2018). Inhibiting growth of *Clostridioides difficile* by restoring valerate, produced by the intestinal microbiota. *Gastroenterology*. 155, 1495–1507. doi: 10.1053/j.gastro.2018.07.014, Luu, M., Pautz, S., Kohl, V. et al. The short-chain fatty acid pentanoate suppresses autoimmunity by modulating the metabolic-epigenetic crosstalk in lymphocytes. *Nat Commun* 10, 760 (2019). <https://doi.org/10.1038/s41467-019-08711-2>; Luu et al., 2021 <https://pubmed.ncbi.nlm.nih.gov/34210970/>; Luu M., Pautz S., Kohl V., Singh R., Romero R., Lucas S., Hofmann J., Raifer H., Vachharajani N., Carrascosa L.C., et al. The Short-Chain Fatty Acid Pentanoate Suppresses Autoimmunity by Modulating the Metabolic-Epigenetic Crosstalk in Lymphocytes. *Nat. Commun.* 2019;10:760. doi: 10.1038/s41467-019-08711-2; Gao, G., Zhou, J., Wang, H. *et al.* Effects of valerate on intestinal barrier function in cultured Caco-2 epithelial cell monolayers. *Mol Biol Rep* **49**, 1817–1825 (2022). <https://doi.org/10.1007/s11033-021-06991-w>; Luu M., Pautz S., Kohl V., Singh R., Romero

R., Lucas S., Hofmann J., Raifer H., Vachharajani N., Carrascosa L.C., et al. The Short-Chain Fatty Acid Pentanoate Suppresses Autoimmunity by Modulating the Metabolic-Epigenetic Crosstalk in Lymphocytes. *Nat. Commun.* 2019;10:760. doi: 10.1038/s41467-019-08711-2, the entireties of each of which are incorporated herein by reference.)

[00102] Yet another aspect of the present disclosure is a method for reducing oxidative stress, strengthening the intestinal barrier, improving immunity, reducing inflammation, improving intestinal barrier, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of N,N-Dimethylglycine in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of N,N-Dimethylglycine in an individual. Research has shown that increasing N,N-Dimethylglycine levels has been linked to the listed benefits (See Cools A. et al. Effect of N,N-dimethylglycine supplementation in parturition feed for sows on metabolism, nutrient digestibility and reproductive performance. *Animal*. 2010;4(12):2004–2011; Bai K. et al. Dietary dimethylglycine sodium salt supplementation improves growth performance, redox status, and skeletal muscle function of intrauterine growth-restricted weaned piglets. *J Anim Sci.* 2021;99(7) skab186; Graber C.D., Goust J.M., Glassman A.D., Kendall R., Loadholt C.B. Immunomodulating Properties of Dimethylglycine in Humans. *J. Infect. Dis.* 1981;143:101–105. doi: 10.1093/infdis/143.1.101; Wang et al. 2022. Heat stress-induced intestinal barrier damage and dimethylglycine alleviates via improving the metabolism function of microbiota gut brain axis. *Ecotoxicology and Environmental Safety* Volume 244, 1 October 2022, 114053. <https://www.sciencedirect.com/science/article/pii/S0147651322008934>; Takahashi et al. 2016. N, N-Dimethylglycine decreases oxidative stress and improves in vitro development of bovine embryos. *J Reprod Dev.* 2016 Apr; 62(2): 209–212. doi: 10.1262/jrd.2015-149, the entireties of each of which are herein incorporated by reference.)

[00103] Yet another aspect of the present disclosure is a method for reducing inflammation, the method comprising administering to an individual in need thereof or at risk thereof any of the compositions disclosed herein. The composition may be administered in an amount effective for increasing levels of Tricarballic acid in the individual. The composition may be administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of Tricarballic acid in an individual. Research has shown that increasing Tricarballic acid levels has been linked

to the listed benefits (See Ashbrook MJ, McDonough KL, Pituch JJ, Christopherson PL, Cornell TT, Selewski DT, Shanley TP, Blatt NB. Citrate modulates lipopolysaccharide-induced monocyte inflammatory responses. Clin Exp Immunol. 2015 Jun;180(3):520-30. doi: 10.1111/cei., the entirety of which is herein incorporated by reference.)

EXAMPLES

[00104] Example 1

[00105] The following non-limiting example generally illustrates the concepts underlying the embodiments disclosed herein.

[00106] The inventors examined the effect of administering the composition disclosed herein, versus lactose-free milk, in 26 healthy adults. Table 1 shows the composition administered versus the control.

	Control	Active Composition
GOS	0 g	9.2 g
Sugar	15 g	6.0 g
Lactose	<0.1 g	1.8 g
Fat	<0.5 g	<0.5 g
Protein	10.2 g	10.2 g
Calories	105 kcal	111 kcal

Table 1: Active composition versus control composition administered to individuals

[00107] Specifically, the inventors employed targeted and untargeted metabolomics for plasma samples and metagenomics for fecal samples. The composition disclosed herein was administered once daily for 2 weeks in a 200 ml drink portion.

[00108] 92 plasma and fecal samples were analyzed using liquid chromatography high resolution mass spectrometer. The features (characterized by their retention time and accurate m/z) were linearized and normalized. The features were annotated by their exact mass (m/z) according to the Human Metabolome database (HMDB). Different statistical approaches were tested to study the effect of the administration of the composition. A statistical analysis was performed with linear models (after log transformation of the data) considering the period and the treatment to study the effect of the administration of the composition. Statistical significance was analyzed with a type 2 analysis of covariance and a false discovery rate estimate was performed. $p < 0.05$ was considered as a significant change.

[00109] Among the significantly annotated features reported in plasma, the inventors found an increase for 3-indole propionic acid (FC of 0.77, $p=0.01$, with its identity confirmed by injecting a pure standard) as shown in Figure 1. Two additional features, which were putatively annotated as 3-hydroxydecanoic acid and 12,13-DiHODE (a lineolic acid derivative), were also significantly increased with the intervention of the current composition ($FC < 0.5$). Figure 2 and Figure 3 show the increases levels of 3-hydroxydecanoic acid and 12,13-DiHODE, respectively, of the intervention group compared to the control group. As seen in Figures 4 and 5, the two uremic toxins indoxyl-sulfate and p-cresol sulfate were significantly ($p<0.05$) reduced in the intervention group with a FC of -0.52 and -0.83, respectively.

[00110] The results of the targeted metabolomics for plasma samples are shown in Figures 6 through 10. Plasma levels of acetate, caprylic acid, nicotinamide, and beta-alanine were significantly increased in the intervention group as shown in Figures 6, 7, 8, and 9, respectively. Additionally, the level of ketone bodies showed an increase in the intervention group as shown in Figure 10, but no dietary intake information was obtained on the study.

[00111] The results of the metagenomics for fecal samples are shown in Figures 11 through 14. *Bifidobacterium* levels significantly increased in the intervention group as shown in Figure 11. Specifically, fecal levels of *B. longum*, *B. adolescentis*, and *B. bifidum* significantly increased in the intervention group as seen in Figures 12, 13, and 14, respectively.

[00112] Figures 15 and 16 show the effect of administration on the *Bifidobacterium* shunt pathways and NAD salvage pathways.

[00113] An overview of targeted and untargeted metabolomics and metagenomics results is shown in the Table 2.

Metabolite	Change	P-value
Acetate	+	0.021
Caprylic Acid	+	0.0252
Nicotinamide	+	0.0245
Beta-Alanine	+	0.0077
<i>Bifidobacterium</i>	+	<0.0001
<i>B. longum</i>	+	<0.05
<i>B. adolescentis</i>	+	<0.05
<i>B. bifidum</i>	+	<0.05
Ketone Bodies	+	0.0291

3-indole propionate	+	0.01
3-Hydroxybutyrate	+	<0.05
12,13-diHODE	+	<0.05
3-hydroxydecanoic acid	+	<0.05
4-cresol sulfate	-	<0.05
Indoxyl sulfate	-	<0.05

Table 2: Metabolite levels after administration of the composition of the present disclosure

[00114] Example 2

[00115] In-vitro batch fermentation experiment was set up to compare the effect of 24h fermentation of GOS or the active composition on the microbial metabolism in healthy adults. For this, the active composition according to Table 3 was subjected to a simulation of upper gastrointestinal tract according to the INFOGEST 2.0 method (Brodkorb et al) to mimic the human upper gastro-intestinal tract digestion before being introduced in the fermenters. This step removed small sugars such as lactose. On the other hand, GOS which is not digested by human gut was directly introduced in the fermenters. The total amount of GOS in the fermenters was the same between the two conditions (see Table 4). A negative control was also introduced to evaluate the basal microbial metabolism after 24h without any substrate addition (NSC). Each condition was tested using fecal inoculum of 12 healthy adult donors. Microbial metabolites (including short chain fatty acids) were measured using a combination of targeted and untargeted metabolomics approaches by ultra-high performance liquid chromatography mass spectrometry (UPLC-MS).

[00116]

	Composition g/100g dry matter
lactose	5.7
glucose	11
galactose	1
GOS	27
Protein	35
Fat	1

[00117] Table 3: Active composition

	NSC- 24h	GOS-24h	Composition after INFOGEST “MLG-H 24h”
Lactose (g/L)	0	0	0
GOS (g/L)	0	4.31	4.3

[00118] Table 4: Lactose and GOS levels of compositions after INFOGEST

[00119] FIGS. 17-21 include box plots showing significant increase in production of beneficial metabolites after 24h fermentation of the composition disclosed herein by comparison to GOS alone or negative control (NSC) using batch fermentation.

[00120] Embodiments

[00121] 1: A method for improving immune health, the method comprising administering to an individual in need thereof a low sugar, low lactose, milk-based composition comprising galactooligosaccharide.

[00122] 2: The method of 1, wherein the milk based composition comprises:
milk protein, preferably at 20-40 % by dry weight of the composition; and
a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition;
preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[00123] 3: The method of 1 or 2, wherein the improving of immune health comprises at least one result selected from the group consisting of: (a) protection from infections, such as viral respiratory infections; (b) protection against pathogens; (c) reducing inflammation; (d) preventing and/or attenuating oxidative stress; (e) improving intestinal barrier; (f) reducing intestinal permeability; (g) promoting growth of *Bifidobacterium*; (h) increasing *Bifidobacterium* shunt pathway; (i) increasing NAD salvage pathway; and (j) and combinations thereof.

[00124] 4: The method of any of 1 to 3, wherein the composition is administered in an amount effective to increase at least one metabolite selected from the group consisting of: 3-indole propionate, acetate, caprylic acid, nicotinamide, beta-alanine, ketone bodies, 3-hydroxybutyrate, 12,13-diHODE, and/or 3-hydroxydecanoic acid.

[00125] 5: The method of any of 1 to 4, wherein the composition is administered in an amount effective to increase one or more *Bifidobacterium*, including but not limited to *B. longum*, *B. adolescentis*, *B. bifidum*.

[00126] 6: A method for one or more of preventing oxidative stress, reducing inflammation, improving the intestinal barrier, and/or reducing intestinal permeability, the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[00127] 7: The method of 6, wherein the composition is administered in an amount effective for increasing levels of 3-indole propionate in the individual.

[00128] 8: The method of any of 6 and 7, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-indole propionate in an individual.

[00129] 9: A method for one or more of preventing and/or treating infections such as viral respiratory infections, such as respiratory syncytial virus (RSV), the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[00130] 10: The method of 9, wherein the composition is administered in an amount effective for increasing levels of acetate in the individual.

[00131] 11: The method of any of 9 and 10, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of acetate in an individual.

[00132] 12: A method for one or more of preventing and/or treating infections such as viral respiratory infections, such as respiratory syncytial virus (RSV), and/or protecting an individual against pathogens, the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[00133] 13: The method of 12, wherein the composition is administered in an amount effective for increasing levels of *Bifidobacterium* in the individual.

[00134] 14: The method of any of 12 and 13, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of *Bifidobacterium* in an individual.

[00135] 15: A method for one or more of reducing and/or preventing oxidative stress, the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 35-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

[00136] 16: The method of 15, wherein the composition is administered in an amount effective for increasing levels of 3-hydroxybutyrate in the individual.

[00137] 17: The method of any of 15 and 16, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-hydroxybutyrate in an individual.

CLAIMS

Claim 1: A method for improving immune health, the method comprising administering to an individual in need thereof a low sugar, low lactose, milk-based composition comprising galactooligosaccharide.

Claim 2: The method of claim 1, wherein the milk-based composition comprises:
milk protein, preferably at 20-40 % by dry weight of the composition; and
a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 32-55% by dry weight of the composition;
preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

Claim 3: The method of claim 1 or claim 2, wherein the improving of immune health comprises at least one result selected from the group consisting of: (a) protection from infections, such as viral respiratory infections; (b) protection against pathogens; (c) reducing inflammation; (d) preventing and/or attenuating oxidative stress; (e) improving intestinal barrier; (f) reducing intestinal permeability; (g) promoting growth of *Bifidobacterium*; (h) increasing *Bifidobacterium* shunt pathway; (i) increasing NAD salvage pathway; and (j) preventing and/or treating allergic asthma, (k) promoting immune homeostasis; (l) preventing and/or treating clostridium difficile infection, (m) cancer immunotherapy;; (o) preventing and/or treating autoimmune diseases; combinations thereof.

Claim 4: The method of any of claims 1 to 3, wherein the composition is administered in an amount effective to increase at least one metabolite selected from the group consisting of: 3-indole propionate, acetate, caprylic acid, nicotinamide, beta-alanine, ketone bodies, 3-hydroxybutyrate, 12,13-diHODE, propionate, indole-3-carboxylate, valerate, N,N-Dimethylglycine, tricarballic acid and/or 3-hydroxydecanoic acid.

Claim 5: The method of any of claims 1 to 4, wherein the composition is administered in an amount effective to increase one or more *Bifidobacterium*, including but not limited to *B. longum*, *B. adolescentis*, *B. bifidum*.

Claim 6: A method for one or more of preventing oxidative stress, reducing inflammation, improving the intestinal barrier, and/or reducing intestinal permeability, the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 32-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

Claim 7: The method of claim 6, wherein the composition is administered in an amount effective for increasing levels of 3-indole propionate in the individual.

Claim 8: The method of any of claims 6 and 7, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-indole propionate in an individual.

Claim 9: A method for one or more of preventing and/or treating infections such as viral respiratory infections, such as respiratory syncytial virus (RSV), the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 32-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

Claim 10: The method of claim 9, wherein the composition is administered in an amount effective for increasing levels of acetate in the individual.

Claim 11: The method of any of claims 9 and 10, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of acetate in an individual.

Claim 12: A method for one or more of preventing and/or treating infections such as viral respiratory infections, such as respiratory syncytial virus (RSV), and/or protecting an individual against pathogens, the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 32-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

Claim 13: The method of claim 12, wherein the composition is administered in an amount effective for increasing levels of *Bifidobacterium* in the individual.

Claim 14: The method of any of claims 12 and 13, wherein the composition is administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of *Bifidobacterium* in an individual.

Claim 15: A method for one or more of reducing and/or preventing oxidative stress, the method comprising administering to an individual in need thereof or at risk thereof a composition comprising:

milk protein, preferably at 20-40 % by dry weight of the composition; and

a mixture of lactose, glucose, galactose and galactooligosaccharide, the mixture preferably at 32-55% by dry weight of the composition;

preferably, the mixture comprising: 0.1-30% by weight of the lactose, 8-40% by weight of the glucose, 0.1-20% by weight of the galactose and 40-90% by weight of the galactooligosaccharide.

Claim 16: The method of claim 15, wherein the composition is administered in an amount effective for increasing levels of 3-hydroxybutyrate in the individual.

Claim 17: The method of any of claims 15 and 16, wherein the composition is

administered to the individual in a unit dosage form, wherein the unit dosage form comprises an amount of the composition effective for increasing levels of 3-hydroxybutyrate in an individual.