



US011873519B2

(12) **United States Patent**
Han et al.

(10) **Patent No.: US 11,873,519 B2**
(45) **Date of Patent: Jan. 16, 2024**

(54) **COMPOSITION FOR PREVENTING AGE-RELATED METABOLIC AND TISSUE DEGENERATIVE CHANGES**

(71) Applicants: **Qinghong Han**, San Diego, CA (US);
Robert M Hoffman, San Diego, CA (US)

(72) Inventors: **Qinghong Han**, San Diego, CA (US);
Robert M Hoffman, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 12 days.

(21) Appl. No.: **17/824,655**

(22) Filed: **May 25, 2022**

(65) **Prior Publication Data**
US 2022/0340891 A1 Oct. 27, 2022

Related U.S. Application Data

(63) Continuation-in-part of application No. 17/225,677, filed on Apr. 8, 2021, now Pat. No. 11,371,036, which is a continuation of application No. 16/165,879, filed on Oct. 19, 2018, now Pat. No. 11,001,826.

(60) Provisional application No. 62/574,693, filed on Oct. 19, 2017.

(51) **Int. Cl.**
C12N 9/88 (2006.01)
A61K 31/675 (2006.01)
A61K 47/02 (2006.01)
A61P 35/00 (2006.01)
A61P 3/10 (2006.01)
A61K 9/00 (2006.01)
A61K 38/51 (2006.01)

(52) **U.S. Cl.**
CPC **C12N 9/88** (2013.01); **A61K 9/0053** (2013.01); **A61K 31/675** (2013.01); **A61K 38/51** (2013.01); **A61K 47/02** (2013.01); **A61P 3/10** (2018.01); **A61P 35/00** (2018.01); **A61K 9/0095** (2013.01); **C12Y 404/01011** (2013.01)

(58) **Field of Classification Search**
CPC C12N 9/88; A61K 9/0053; A61K 31/675; A61K 38/51; A61K 47/02; A61K 9/0095; A61P 3/10; A61P 35/00; C12Y 404/01011
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

11,001,826 B2 * 5/2021 Han A61K 31/675
11,371,036 B2 * 6/2022 Han A61P 3/10
2005/0036981 A1 * 2/2005 Yagi A61K 38/51
424/94.4

OTHER PUBLICATIONS

Ingenbleek Y. et al. Nutritional Essentiality of Sulfur in Health and Disease. Nutrition Reviews 71(7)413-432, Jul. 2013. (Year: 2013).*
Hoffman, R. Methioninase: A Therapeutic for Diseases Related to Altered Methionine Metabolism and Transmethylation . . . The Japan Human Cell Society, Human Cell 10(1)69-80, 1997. (Year: 1997).*
El-Sayed, A. Microbial L-Methioninase: Production, Molecular Characterization, and Therapeutic Applications. Applied Microbiology and Biotechnology 86(2)445-467, Mar. 2010. (Year: 2010).*
Hoffman, R. et al. Afterword: Oral Methioninase—Answer to Cancer and Fountain of Youth? Methods in Molecular Biology vol. 1866, Chapter 24, pp. 311-322, 2019. (Year: 2019).*
Jia, K. et al. Clonostachys rosea Demethiolase STR3 Controls the Conversion of Methionine into Methanethiol. Scientific Reports Feb. 1-11, 2016. (Year: 2016).*

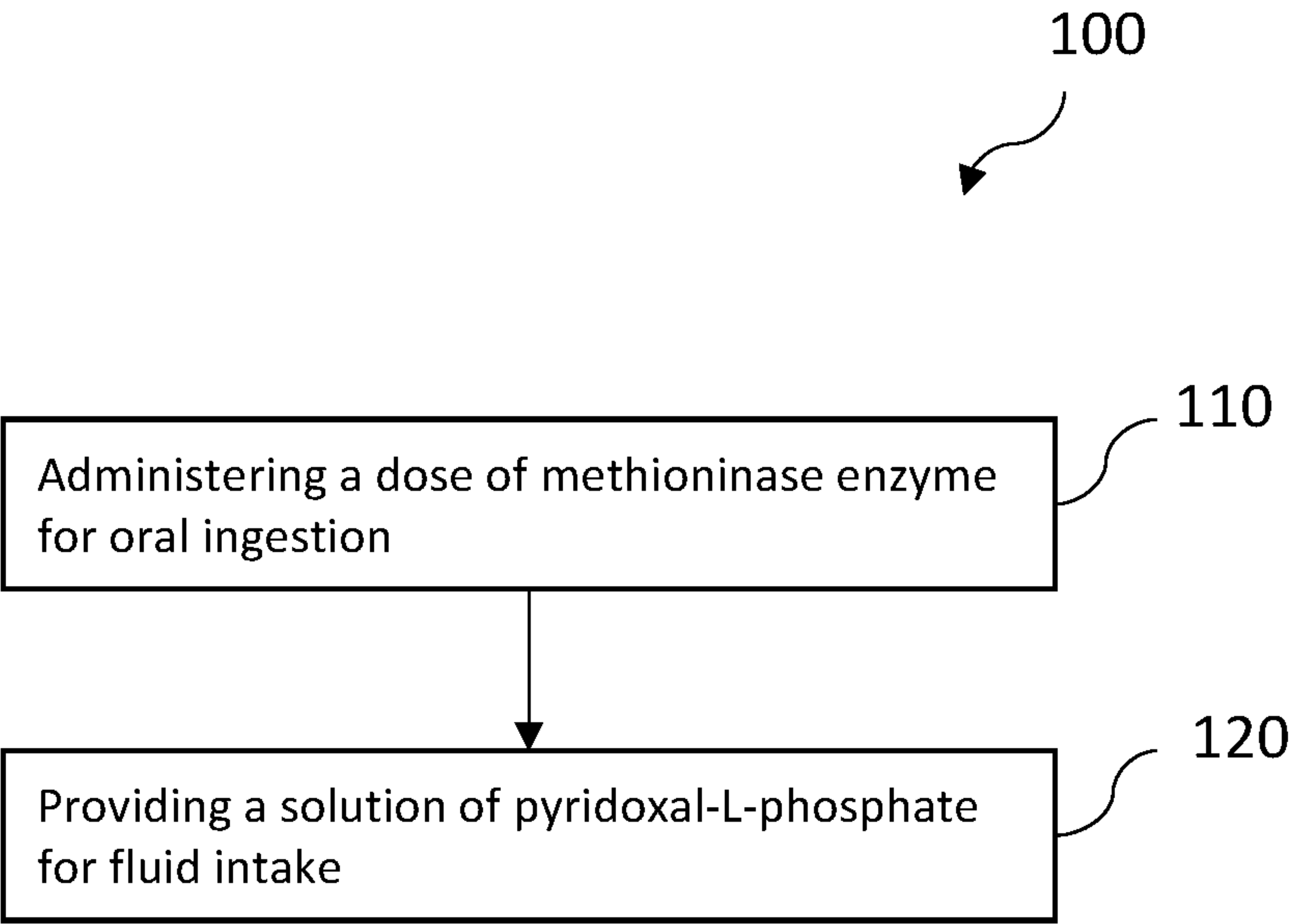
* cited by examiner

Primary Examiner — Aaron J Kosar
(74) Attorney, Agent, or Firm — Barry Choobin; Patent 360

(57) **ABSTRACT**

A composition and method for reversing or preventing age-related metabolic and tissue degenerative changes in individuals. The method includes administering, orally, an effective amount of a first composition having methioninase enzyme. The method further includes administering, by a route other than the oral route, such as a parenteral route, an effective amount of a second composition having methioninase enzyme. The method further includes the steps of orally and/or parentally administering pyridoxal-L-phosphate.

19 Claims, 1 Drawing Sheet



1

COMPOSITION FOR PREVENTING AGE-RELATED METABOLIC AND TISSUE DEGENERATIVE CHANGES

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of a U.S. Non-Provisional patent application Ser. No. 17/225,677 filed on Apr. 8, 2021, which is a continuation application of a U.S. Non-Provisional patent application Ser. No. 16/165,879 filed Oct. 10, 2018, which claims priority from a U.S. Provisional Patent Application No. 62/574,693 filed Oct. 19, 2017, the entire contents of the above three applications are incorporated herein by reference.

FIELD OF INVENTION

This invention relates to compositions and methods for lowering serum methionine levels. In particular, the invention involves an orally administered composition including a methioninase enzyme and methods of use.

BACKGROUND

Metastatic melanoma is a recalcitrant cancer, with a five-year survival rate of only 7%-30%. There is currently no cure for stage III and stage IV disease.

An excessive requirement for methionine appears to be a metabolic defect in cancer, and the only known such metabolic defect shared by cells across most types of cancer cells. This elevated methionine ("MET") use by cancer cells is termed "methionine dependence" or "methionine addiction". It has been previously shown that growth of cancer cells can be selectively arrested by methionine deprivation, such as with recombinant methioninase ("r-METase").

Restriction of dietary MET reduces serum MET levels and is known to reverse age-related changes and increase lifespan in some animals, decrease the severity of or eliminate insulin-resistant diabetes mellitus, and impair or reverse the growth of certain malignancies. Severe dietary MET restriction is necessary to achieve observable effects and, generally, requires elimination of essentially all animal protein and many plant-based foods from the diet.

Means other than dietary restriction has been used to decrease serum MET. Targeting MET by administration of recombinant methioninase ("rMETase") can arrest the growth of cancer cells in vitro and in vivo, presumably by decreasing MET concentration in the tumor interstitial microenvironment. Because METase was thought to be hydrolysed at an acid pH in the stomach and then further degraded by enterokinase-activated proteolytic enzymes in the small bowel, exploitation of METase to lower serum concentrations of methionine with or without dietary methionine restriction was thought to require METase to be administered parenterally.

Ideally, a composition containing rMETase which is effective following oral administration is needed to exploit METase to lower serum MET levels without the need for severe dietary restriction or parental dosing.

SUMMARY OF THE INVENTION

Embodiments of the present invention include a METase-containing composition effective in reducing serum MET levels and methods of use to treat cancer, insulin-resistant

2

diabetes mellites, and to reverse age-related metabolic and tissue degenerative changes in animals and humans.

Disclosed is a composition for oral administration to reduce serum methionine levels in an individual comprising a methioninase enzyme; a cofactor; and a phosphate-buffered saline solution.

In some embodiments, the methioninase enzyme is a L-methionine α -deamino- γ -mercaptomethane lyase in some embodiments, the cofactor is pyridoxal-L-phosphate. In some embodiments, the pyridoxal-L-phosphate is in an aqueous solution at a concentration of about twenty (20) millimoles per liter of water.

Disclosed is a method for suppressing the growth of a malignancy within an individual comprising the steps of administering an oral dose of methioninase enzyme; and providing a solution of pyridoxal-L-phosphate for fluid intake.

In some embodiments, the dose of methioninase enzyme is about 0.1-10 mg/kg/day of body weight.

In some embodiments, the malignancy is melanoma. In some embodiments, the malignancy is Ewing's sarcoma or other cancer types.

In some embodiments, the individual is a human individual. In some embodiments, the individual is a non-human individual. In some embodiments, the non-human individual is a mouse.

Disclosed is a method for preventing or reversing a disease condition in an individual comprising the steps of administering an oral dose of methioninase enzyme; and providing a solution of pyridoxal-L-phosphate for fluid intake.

In some embodiments, the disease condition is cancer. In some embodiments, the disease condition is insulin resistant diabetes mellitus. In some embodiments, the disease condition is condition related to aging.

In some embodiments, the individual is a human individual. In some embodiments, the individual is a non-human individual.

In one aspect, disclosed is a method for reversing or preventing age-related metabolic and tissue degenerative changes in an individual in need thereof, the method comprising the steps of administering, orally, an effective amount of a first composition having methioninase enzyme; and administering, by a route other than the oral route, an effective amount of a second composition having methioninase enzyme. The method further includes the steps of administering orally, fluid including pyridoxal-L-phosphate. The second composition further includes pyridoxal-L-phosphate. The first composition further includes flavors, sweeteners, and binders. The fluid is a solution of pyridoxal-L-phosphate in drinking water. The route other than the oral route is a parenteral route.

The foregoing and other features and advantages of the present invention will be apparent from the following more detailed description of the particular embodiments of the invention, as illustrated in the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a flow chart of a method of oral administration of a METase composition to treat a disease condition.

DETAILED DESCRIPTION

There are multiple instances wherein rMETase has been shown effective to suppress the growth of cancer cells. As previously mentioned, targeting MET by recombinant

3

methioninase (“rMETase”) can arrest the growth of cancer cells in vitro and in vivo. Administration of rMETase by intra-peritoneal injection (“ip-rMETase”) inhibits tumor growth in a patient-derived orthotopic xenograft (“PDOX”) model of a BRAF-V600E mutant melanoma. rMETase in combination with a first-line melanoma drug temozolomide (TEM) is significantly more efficacious than either of these monotherapies. Additionally, rMETase is efficacious against Ewing’s sarcoma in a PDOX model, wherein rMETase effectively reduced tumor growth compared to untreated control mice. Serum and tumor MET levels were lower in the rMETase group, versus controls.

MET dependence or addiction is a general metabolic defect in cancer. Deprivation of MET arrests growth and induces a tumor-selective S/G2-phase cell cycle arrest of cancer cells in vitro and in vivo.

MET dependence or addiction is believed to be due to excess use of MET for aberrant transmethylation reactions in the cancer cell, termed the “Hoffman effect,” analogous to the Warburg effect for elevated glucose use in cancer. For example, the excessive and aberrant use of MET by cancer cells is strongly observed using positron emission tomography (“PET”) scanning following administration of a ^{11}C -MET-labeled substrate, where uptake of ^{11}C -MET results in a very strong and selective tumor signal compared with normal tissue background. Additionally, ^{11}C -MET is superior to [^{18}C] fluorodeoxyglucose (“FEG”)-PET for PET imaging of cancer, suggesting MET dependence is more cancer-specific than glucose dependence.

In humans, MET is sourced mainly from food and restriction of dietary MET intake results in lower serum MET levels. MET restriction through diet with low protein content is problematic, however, because the severe restriction of dietary protein necessary to lower serum MET levels does not allow the maintenance of good nutritional status. Use of dietary MET restriction to lower MET levels is also limited by metabolic pathways to also source MET by breaking down protein in tissues. Conversely, the use of parenteral rMETase leads to further reduction of plasma MET and is accompanied by reduction in tumor size.

When compared with ip-rMETase, oral rMETase (“o-rMETase”) is at least as effective as an anticancer agent than ip-rMETase, provided administration of the o-rMETase is accompanied by pyridoxal-L-phosphate (“PLP”) in drinking water.

An oral composition of recombinant METase that can be used for cancer treatment, cancer prevention, and anti-aging, ingested on a chronic basis along with PLP is disclosed. Various concentrations of o-rMETase are used, in some embodiments, for the purposes mentioned above.

In a non-limiting experimental example, melanoma PDOX nude mice were randomized into four (4) groups of five (5) mice each: 1) untreated control; 2) ip-rMETase (100 units, intra-peritoneal for fourteen (14) consecutive days); 3) o-rMETase (100 units/2.0 mg. in phosphate-buffered saline (“PBS”) for fourteen consecutive days; and 4) o-rMETase and ip-rMETase (100 units oral rMETase plus 100 units intraperitoneal rMETase) for fourteen consecutive days. Additionally, drinking water containing 100 $\mu\text{mol/L}$ of PLP (1.0 ml of 20 mmol/L PLP solution added to 200 ml drinking water, mixed fresh daily) was provided to all mice for the fourteen consecutive days duration of the study. The o-rMETase (100 units/2.0 mg in PBS) was administered daily by gavage using a stainless-steel feeding needle.

All treatments inhibited tumor growth by day fourteen after treatment initiation, compared to untreated control mice (ip-rMETase, $p < 0.0001$; o-rMETase, $p < 0.0001$;

4

o-rMETase+rMETase, $p < 0.0001$). The o-rMETase treatment was significantly more effective than ip-rMETase ($p = 0.0086$). The o-rMETase & ip-rMETase combination was significantly more effective than either monotherapy ($p = 0.0005$; o-rMETase, $p = 0.0367$).

Post-treatment plasma MET levels significantly decreased compared to untreated controls (ip-rMETase, $p = 0.122$; o-rMETase, $p = 0.003$; o-rMETase+ip-rMETase, $p < 0.0001$ (FIG. 3). Body-weight loss was not observed in any treatment group (FIG. 4). There were no animal deaths in any group. These results show the safety of o-rMETase and its potential for chronic cancer treatment in a clinical setting.

Mice

Athymic nu/nu nude mice (AntiCancer Inc., San Diego, Calif.), four (4) to six (6) weeks old were used in this study. Mice were housed in a barrier facility in a high-efficacy particulate arrestance (“HEPA”)-filtered rack under standard conditions of 12-hour light/dark cycles. The animals were fed an autoclaved laboratory rodent diet. All animal studies were conducted in accordance with the principles and procedures outlined in the National Institutes of Health Guide for the Care and Use of Animals under Assurance Number A3873-1. All mouse surgical procedures and imaging were performed with the animals anesthetized by subcutaneous injection of a ketamine mixture comprising 0.02 ml solution of ketamine at a dose of 20 mg/kg, 15.2 mg/kg xylazine, and 0.48 mg/kg acepromazine maleate. The response of animals during surgery was monitored to ensure adequate depth of anaesthesia. The animals were observed daily and humanely sacrificed by CO_2 inhalation if they met the following humane endpoint criteria: severe tumor burden, defined as any tumor greater than 20 mm in diameter; prostration; significant body weight loss; difficulty breathing; rotational motion; and drop in body temperature.

Patient-Derived Tumor

A 75-year-old female patient was previously diagnosed with a BRAF-V600E melanoma of the right chest wall. The tumor was previously resected in the Department of Surgery, University of California, Los Angeles (“USLA”). Written informed consent was provided by the patient, and the Institutional Review Board (“IRB”) of UCLA approved this experiment.

Establishment of PDOX Models of Melanoma by Surgical Orthotopic Implantation (SOI)

Subcutaneously grown BRAF V600 mutant melanoma was harvested and cut into small fragments measuring about 3 mm^2 . After nude mice were anesthetized with the ketamine solution described herein above, a skin incision was made on the right chest into the chest wall, which was split to make space for the melanoma tissue fragment. A single tumor fragment was implanted orthotopically into the space to establish the PDOX model. The wound was closed with 6-0 nylon suture (Ethicon, Inc., NJ, USA),

Recombinant Methioninase (rMETase) Production

Recombinant L-methionine α -deamino- γ -mercaptomethane lyase (methioninase, METase) [EC 4.4.1.11] from *Pseudomonas putida* has been previously cloned and was

5

produced in *Escherichia coli* (AntiCancer, Inc., San Diego, Calif.). rMETase is a homotetrameric PLP enzyme of 172-kDa molecular mass.

Formulation of o-rMETase and pyridoxal-L-phosphate (PLP) supplement

Mouse drinking water contained 100 $\mu\text{mol/L}$ PLP. One (1.0) ml of 20 nmol/L PLP was added to 200 ml drinking water and made fresh daily. Approximately two (2) mg (100 units) rMETase in PBS was administered daily by gavage using a stainless steel feeding needle.

Treatment Study Design in the PDOX Model of Melanoma

BRAF V600E mutant melanoma PDOX nude mice were randomized into four (4) groups of five (5) mice each. The four groups included an: 1) untreated control; 2) ip-rMETase (100 units, intra-peritoneal); 3) o-rMETase (100 units/2.0 mg. orally in PBS and 4) combination of o-rMETase and ip-rMETase (100 units oral rMETase plus 100 units intraperitoneal rMETase). Each group was treated for fourteen (14) consecutive days.

Determination of Plasma Methionine

The plasma methionine concentration was measured using a precolumn derivatization, followed by high-performance liquid chromatography separation based on a previously-described method with modification. A 10- μl plasma sample or methionine standard was used. The plasma methionine was identified by the retention time of a methionine standard curve. The limit of detection was 0.5 μM methionine. The upper limit of detection for methionine for methionine assay is about 100 μM .

Statistical Analysis

JMP version 11.0 was used for all statistical analysis. Significant differences for continuous variables were determined using the Mann-Whitney U test. Line graphs expressed average values and error bar showed standard deviation. A probability value of less than or equal to 0.05 was considered statistically significant.

Orally administered rMETase is significantly more effective at inhibiting melanoma tumor growth than intraperitoneal rMETase. There is potential for clinical development of treatment methods exploiting compositions containing o-rMETase administered with PLP as an agent for chronic cancer therapy and prevention, and, possibly, for life extension because dietary MET reduction extends lifespan in many animal models.

FIG. 1 is a flow chart of a method of oral administration of a METase composition to treat a disease condition. FIG. 1 shows a method 100 comprising an administering step 110 and a providing step 120.

Administering step 110, in some embodiments, comprises administering an oral dose of methioninase enzyme. Wherein the disease condition is a disease condition in a human individual, administering step 110 comprises giving the individual an oral formulation of the methioninase enzyme, which, in some embodiments, includes one or more excipients, such as flavors, sweeteners, binders, other excipients used in oral dosing of medications and other compositions for human individuals. This is not meant to be limiting; in some embodiments, method 100 is undertaken with a

6

non-human individual, such as a pet animal, a livestock animal, or a laboratory animal such as a mouse.

Providing step 120, in some embodiments, comprises providing a solution of pyridoxal-L-phosphate for fluid intake. The solution may additionally comprise a flavor, a sweetener, a thickener, and the like, in some embodiments.

Variations of method 100 are used, in some embodiments, to suppressing the growth of a malignancy, including, but not limited to, malignant melanoma and Ewing's sarcoma. Because the tumor suppressive effects of lowering the plasma concentration of methionine in the tumor microenvironment are known for many malignancies, this disclosure anticipates the use of method 100 to treat many other malignancies. It is additionally within the scope of this disclosure for method 100 to be used as chronic suppressive therapy for melanoma, Ewing's sarcoma, and many other malignancies. Moreover, it is within the scope of this disclosure to employ step 110 and step 120 of method 100 to treat insulin-resistant diabetes, and in the treatment various neurodegenerative, musculoskeletal degenerative, inflammatory, and immunodeficiencies associated with normal aging process, and to reverse many effects of normal aging. It is additionally within the scope of method 100 to treat other diseases or conditions wherein reduction of plasma methionine levels is beneficial in the treatment, suppression, or prevention of the condition.

In certain implementations, disclosed is a method for reducing serum methionine levels in an individual in need thereof. Also, disclosed is a method for suppressing the growth of a malignancy within an individual. Also, disclosed is a method for treating insulin-resistant diabetes mellitus in an individual. Also, disclosed is a method for reversing age-related metabolic and tissue degenerative changes in an individual in need thereof. The method includes the steps of orally administering to an individual in need thereof a composition that includes methioninase enzyme. The method further includes the step of orally administering fluid that includes a solution of pyridoxal-L-phosphate. The solution of pyridoxal-L-phosphate can be the pyridoxal-L-phosphate in water, in psychological saline, and more preferably in the drinking water.

In certain implementation, the composition can further include flavors, sweeteners, and binders. In a preferred embodiment, the methioninase enzyme is not PEGylated. The composition can further include pyridoxal-L-phosphate as a cofactor and phosphate-buffered saline solution. The pyridoxal-L-phosphate can be an aqueous solution at a concentration of about twenty (20) millimoles per litre of water.

In certain implementations, disclosed is an oral unit dose form for reducing serum methionine levels in an individual in need thereof consisting essentially of methioninase enzyme which is not PEGylated.

In certain implementations, the method may further include the step of additionally administering the methioninase enzyme through a route other than the oral route. For example, the methioninase enzyme can also be administered through a parental route, sublingual route (oral route herein does not include sublingual route), intranasal route, rectal route, or any other route known to a skilled person for administering drugs/medicines to human body. The methioninase enzyme through the alternate route can be formulated according to the route of administration, and any such formulation and method of making the formulations are within the scope of the present invention. For example, formulation of methioninase enzyme can include phosphate buffered saline for parenteral administration. The formula-

7

tion for alternate route of administration may also include pyridoxal-5-phosphate in suitable concentration. For example, phosphate buffered saline containing 100 $\mu\text{mol/L}$ of pyridoxal-5-phosphate (PLP) can be administered parentally along with oral administration of methioninase enzyme and/or pyridoxal-5-phosphate (PLP).

In certain implementations, the dose of methioninase enzyme and/or pyridoxal-5-phosphate (PLP) for alternate route of administration can be determined through suitable experimentations known to a skilled person. The dose of alternate routes may depend upon oral dose of methioninase enzyme. For example, the dose of methioninase enzyme for intravenous administration can be in a range of about 1,000 units-10,000 units; for intraperitoneal administration can be in a range of about 2,000 units-10,000 units; for intramuscular administration can be in a range of about 1,000 units-10,000 units; for subcutaneous administration can be in a range of about 1,000 units-10,000 units; for intra-arterial administration can be in a range of about 1,000 units-10,000 units; and for sublingual administration can be in a range of about 1,000 units-10,000 units.

The embodiments and examples set forth herein are presented to best explain the present invention and its practical application, and to thereby enable those of ordinary skill in the art to make and use the invention. However, those of ordinary skill in the art will recognize that the foregoing description and examples have been presented for the purposes of illustration and example only. The description as set forth is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the teachings above and are intended to fall within the scope of the appended claims.

What is claimed is:

1. A method for suppressing or preventing growth of malignancy in an individual in need thereof, the method comprising the steps of:

administering, orally, an effective amount of a first composition comprising methioninase enzyme; and
administering, by a route other than the oral route, an effective amount of a second composition comprising methioninase enzyme.

2. The method according to claim 1, wherein the method further comprises the steps of:

administering orally, fluid comprising pyridoxal-L-phosphate.

3. The method according to claim 2, wherein the second composition further comprises pyridoxal-L-phosphate.

4. The method according to claim 2, wherein the fluid is a solution of pyridoxal-L-phosphate in drinking water.

8

5. The method according to claim 1, wherein the first composition further comprises flavors, sweeteners, and binders.

6. The method according to claim 1, wherein the route is a parenteral route.

7. The method according to claim 1, wherein the route is a sublingual route.

8. A method for treating insulin resistant diabetes mellitus in an individual in need thereof, the method comprising the steps of:

administering, orally, an effective amount of a first composition comprising methioninase enzyme; and

administering, by a route other than the oral route, an effective amount of a second composition comprising methioninase enzyme.

9. The method according to claim 8, wherein the method further comprises the steps of:

administering orally, fluid comprising pyridoxal-L-phosphate.

10. The method according to claim 9, wherein the second composition further comprises pyridoxal-L-phosphate.

11. The method according to claim 9, wherein the fluid is a solution of pyridoxal-L-phosphate in drinking water.

12. The method according to claim 8, wherein the first composition further comprises flavors, sweeteners, and binders.

13. The method according to claim 8, wherein the route is a parenteral route.

14. A method for reversing or preventing age-related metabolic and tissue degenerative changes in an individual in need thereof, the method comprising the steps of:

administering, orally, an effective amount of a first composition comprising methioninase enzyme; and
administering, by a route other than the oral route, an effective amount of a second composition comprising methioninase enzyme.

15. The method according to claim 14, wherein the method further comprises the steps of:

administering orally, fluid comprising pyridoxal-L-phosphate.

16. The method according to claim 15, wherein the second composition further comprises pyridoxal-L-phosphate.

17. The method according to claim 15, wherein the fluid is a solution of pyridoxal-L-phosphate in drinking water.

18. The method according to claim 14, wherein the first composition further comprises flavors, sweeteners, and binders.

19. The method according to claim 14, wherein the route other than the oral route is a parenteral route.

* * * * *