

A VARIANT FORM OF URATE OXIDASE AND USE THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to and the benefit of U.S. provisional application Serial No. 60/670,541, filed on April 11, 2005, the disclosure of which is being incorporated by reference herein.

FIELD OF THE INVENTION

5 [0002] The present invention relates to genetically modified proteins with uricolytic activity. More specifically, the invention relates to proteins comprising truncated urate oxidases and methods for producing them.

BACKGROUND OF THE INVENTION

[0003] The terms urate oxidase and uricase are used herein interchangeably. Urate oxidases
10 (uricases; E.C. 1.7.3.3) are enzymes which catalyze the oxidation of uric acid to a more soluble product, allantoin, a purine metabolite that is more readily excreted. Humans do not produce enzymatically active uricase, as a result of several mutations in the gene for uricase acquired during the evolution of higher primates. Wu, X, *et al.*, (1992) *J Mol Evol* 34:78-84, incorporated herein by reference in its entirety. As a consequence, in susceptible individuals, excessive
15 concentrations of uric acid in the blood (hyperuricemia) can lead to painful arthritis (gout), disfiguring urate deposits (tophi) and renal failure. In some affected individuals, available drugs such as allopurinol (an inhibitor of uric acid synthesis) produce treatment-limiting adverse effects or do not relieve these conditions adequately. Hande, KR, *et al.*, (1984) *Am J Med* 76:47-56; Fam, AG, (1990) *Bailliere's Clin Rheumatol* 4:177-192, each incorporated herein by
20 reference in its entirety. Injections of uricase can decrease hyperuricemia and hyperuricosuria, at least transiently. Since uricase is a foreign protein in humans, even the first injection of the

unmodified protein from *Aspergillus flavus* has induced anaphylactic reactions in several percent of treated patients (Pui, C-H, *et al.*, (1997) *Leukemia* 11:1813-1816, incorporated herein by reference in its entirety), and immunologic responses limit its utility for chronic or intermittent treatment. Donadio, D, *et al.*, (1981) *Nouv Presse Med* 10:711-712; Leaustic, M, *et al.*, (1983) *Rev Rhum Mal Osteoartic* 50:553-554, each incorporated herein by reference in its entirety.

[0004] The present invention is related to mutant recombinant uricase proteins having truncations and enhanced structural stability.

SUMMARY OF THE INVENTION

[0005] It is an objective of the present invention to provide novel recombinant uricase proteins. The proteins of the invention contemplated will be truncated and have mutated amino acids relative to naturally occurring uricase proteins.

[0006] The subject invention provides a mutant recombinant uricase comprising the amino acid sequence of SEQ ID NO. 8. Also provided is a mutant recombinant uricase comprising the amino acid sequence of SEQ ID NO. 13.

[0007] An additional objective of the present invention to provide a means for metabolizing uric acid comprising a novel recombinant uricase protein having uricolytic activity. Uricolytic activity is used herein to refer to the enzymatic conversion of uric acid to allantoin.

[0008] In an embodiment, the uricase comprises the amino acid sequence of position 8 through position 287 of SEQ ID NO. 7 or SEQ ID NO. 12. Also provided are uricases comprising the amino acid sequence of SEQ ID NO. 8 or SEQ ID NO. 13. In an embodiment, the uricase comprises an amino terminal amino acid, wherein the amino terminal amino acid is alanine, glycine, proline, serine, or threonine. In a particular embodiment, the amino terminal amino acid is methionine.

[0009] Also provided are isolated nucleic acids comprising a nucleic acid sequence which encodes a uricase of the invention. In particular embodiments, the uricase encoding nucleic acid

is operatively linked to a heterologous promoter, for example, the *osmB* promoter. Also provided are nucleic acid vectors comprising the uricase encoding nucleic acid, host cells comprising such vectors, and methods for producing a uricase comprising the steps of culturing such host cell under conditions such that the nucleic acid sequence is expressed by the host cell and isolating the expressed uricase.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] **Figure 1** illustrates the structure of plasmid pOUR-P- Δ N-ks-1. Numbers next to restriction sites indicate nucleotide position, relative to *Hae*II site, designated as 1. Restriction sites which are lost during cloning are marked in parenthesis.

[0011] **Figure 2** depicts the DNA and the deduced amino acid sequences of Pig-KS- Δ N uricase (SEQ ID NO. 9 and SEQ ID NO. 7, respectively). The amino acid numbering in Figure 2 is relative to the complete pig uricase sequence. Following the initiator methionine residue, a threonine replaces aspartic acid 7 of the pig uricase sequence. The restriction sites that are used for the various steps of subcloning are indicated. The 3' untranslated sequence is shown in lowercase letters. The translation stop codon is indicated by an asterisk.

[0012] **Figure 3** shows relative alignment of the deduced amino acid sequences of the various recombinant pig (SEQ ID NO. 11), PBC- Δ NC (SEQ ID NO. 12), and Pig-KS- Δ N (SEQ ID NO. 7) uricase sequences. The asterisks indicate the positions in which there are differences in amino acids in the Pig-KS- Δ N as compared to the published pig uricase sequence; the circles indicate positions in which there are differences in amino acids in Pig-KS- Δ N as compared to PBC- Δ N. Dashed lines indicate deletion of amino acids.

[0013] **Figure 4** depicts SDS-PAGE of pig uricase and the highly purified uricase variants produced according to Examples 1 - 3. The production date (month/ year) and the relevant lane number for each sample is indicated in the key below. The Y axis is labeled with the weights of molecular weight markers, and the top of the figure is labeled with the lane numbers. The lanes

are as follows: Lane 1 – Molecular weight markers; Lane 2 – Pig KS-ΔN (7/98); Lane 3 – Pig (9/98); Lane 4 – Pig KS (6/99); Lane 5 – Pig KS (6/99); Lane 6 – Pig-ΔN (6/99); Lane 7 – Pig KS-ΔN (7/99); Lane 8 – Pig KS-ΔN (8/99).

[0014] **Figure 5** depicts the pharmacokinetic profiles of PEGylated (9x10 kD) Pig-KS-ΔN

uricase in rats following IM (intramuscular), SC (subcutaneous), and IV (intravenous) injections, as determined by monitoring enzymatic activity in blood samples. Uricase activity in plasma samples, which are collected at the indicated time points, is determined using the colorimetric assay. Activity values (mAU = milli-absorbance units) represent the rate of enzymatic reaction per 1 μl of plasma sample. The bioavailability (amount of drug reaching the circulation relative to an IV injection) of uricase injected was calculated from the area under the curve of the graph.

[0015] **Figure 6** depicts the pharmacokinetic profiles of PEGylated (9x10 kD) Pig-KS-ΔN

uricase in rabbits following IM (intramuscular), SC (subcutaneous), and IV (intravenous) injections, as determined by monitoring enzymatic activity in blood samples. Uricase activity in plasma samples collected at the indicated time points is determined using a colorimetric assay.

Activity values (mAU = milli-absorbance units) represent the rate of enzymatic reaction per 1 μl of plasma sample. The bioavailability (amount of drug reaching the circulation relative to an IV injection) of uricase injected was calculated from the area under the curve of the graph.

[0016] **Figure 7** depicts the pharmacokinetic profiles of PEGylated (9x10 kD) Pig-KS-ΔN

uricase in dogs following IM (intramuscular), SC (subcutaneous), and IV (intravenous)

injections, as determined by monitoring enzymatic activity in blood samples. Uricase activity in plasma samples, which are collected at the indicated time points, is determined using the colorimetric assay. Activity values (mAU = milli-absorbance units) represent the rate of enzymatic reaction per 1 μl of plasma sample. The bioavailability (amount of drug reaching the circulation relative to an IV injection) of uricase injected was calculated from the area under the

curve of the graph.

[0017] **Figure 8** depicts the pharmacokinetic profiles of PEGylated (9x10 kD) Pig-KS-ΔN uricase in pigs following IM (intramuscular), SC (subcutaneous), and IV (intravenous) injections, as determined by monitoring enzymatic activity in blood samples. Uricase activity in plasma samples, which are collected at the indicated time points, is determined using the colorimetric assay. Activity values (mAU = milli-absorbance units) represent the rate of enzymatic reaction per 1 μl of plasma sample. The bioavailability (amount of drug reaching the circulation relative to an IV injection) of uricase injected was calculated from the area under the curve of the graph.

DETAILED DESCRIPTION OF THE INVENTION

[0018] Previous studies teach that when a significant reduction in the immunogenicity and/or antigenicity of uricase is achieved by PEGylation, it is invariably associated with a substantial loss of uricolytic activity. The safety, convenience and cost-effectiveness of biopharmaceuticals are all adversely impacted by decreases in their potencies and the resultant need to increase the administered dose. Thus, there is a need for a safe and effective alternative means for lowering elevated levels of uric acid in body fluids, including blood. The present invention provides a mutant recombinant uricase comprising the amino acid sequence of SEQ ID NO. 7, SEQ ID NO. 8, SEQ ID NO. 12 or SEQ ID NO. 13.

[0019] Uricase, as used herein, includes individual subunits, as well as the tetramer, unless otherwise indicated.

[0020] In a particular embodiment, the uricase has an amino terminal methionine. This methionine may be removed by post-translational modification. In particular embodiments, the amino terminal methionine is removed after the uricase is produced. In a particular embodiment, the methionine is removed by endogenous bacterial aminopeptidase. The penultimate amino acid may one that allows removal of the N-terminal methionine by bacterial methionine aminopeptidase (MAP). Amino acids allowing the most complete removal of the N-terminal

methionine are alanine, glycine, proline, serine, and threonine. In a particular embodiment, the uricase comprises two amino terminal amino acids, wherein the two amino terminal amino acids are a methionine followed by an amino acid selected from the group consisting of alanine, glycine, proline, serine, and threonine.

5 **[0021]** The subject invention provides a nucleic acid sequence encoding the uricase.

[0022] The subject invention provides a vector comprising the nucleic acid sequence.

[0023] In a particular embodiment, the uricase is isolated. In a particular embodiment, the uricase is purified. In particular embodiments, the uricase is isolated and purified.

10 **[0024]** The subject invention provides a host cell comprising a vector comprising a uricase encoding nucleic acid sequence.

[0025] The subject invention provides a method for producing the uricase encoding nucleic acid sequence, comprising modification by PCR (polymerase chain reaction) techniques of a nucleic acid sequence encoding a uricase. One skilled in the art appreciates that a desired nucleic acid sequence is prepared by PCR via synthetic oligonucleotide primers, which are
15 complementary to regions of the target DNA (one for each strand) to be amplified. The primers are added to the target DNA (that need not be pure), in the presence of excess deoxynucleotides and Taq polymerase, a heat stable DNA polymerase. In a series (typically 30) of temperature cycles, the target DNA is repeatedly denatured (around 90°C), annealed to the primers (typically at 50-60°C) and a daughter strand extended from the primers (72°C). As the daughter strands
20 themselves act as templates for subsequent cycles, DNA fragments matching both primers are amplified exponentially, rather than linearly.

[0026] The subject invention provides a method for producing a mutant recombinant uricase comprising transfecting a host cell with the vector, wherein the host cell expresses the uricase, isolating the mutant recombinant uricase from the host cell, isolating the purified mutant
25 recombinant uricase, for example, using chromatographic techniques, and purifying the mutant

recombinant uricase. For example, the uricase can be produced according to the methods described in International Patent Publication No. WO 00/08196 and U.S. Application No. 60/095,489, incorporated herein by reference their entireties.

[0027] In a preferred embodiment, the host cell is treated so as to cause the expression of the mutant recombinant uricase. One skilled in the art is aware that transfection of cells with a vector is usually accomplished using DNA precipitated with calcium ions, though a variety of other methods can be used (e.g. electroporation).

[0028] The uricase may be isolated and/or purified by any method known to those of skill in the art. Expressed polypeptides of this invention are generally isolated in substantially pure form. Preferably, the polypeptides are isolated to a purity of at least 80% by weight, more preferably to a purity of at least 95% by weight, and most preferably to a purity of at least 99% by weight. In general, such purification may be achieved using, for example, the standard techniques of ammonium sulfate fractionation, SDS-PAGE electrophoresis, and affinity chromatography. The uricase is preferably isolated using a cationic surfactant, for example, cetyl pyridinium chloride (CPC) according to the method described in copending United States patent application filed on April 11, 2005 having application no. 60/670,520 and attorney docket number 103864.146644, entitled Purification Of Proteins With Cationic Surfactant, incorporated herein by reference in its entirety.

[0029] In an embodiment of the invention, the vector is under the control of an osmotic pressure sensitive promoter. A promoter is a region of DNA to which RNA polymerase binds before initiating the transcription of DNA into RNA. An osmotic pressure sensitive promoter initiates transcription as a result of increased osmotic pressure as sensed by the cell.

[0030] The uricase of the invention includes uricase that is conjugated with a polymer, for example, a uricase conjugated to polyethylene glycol, i.e., PEGylated uricase.

[0031] In an embodiment of the invention, a pharmaceutical composition comprising the uricase is provided. In one embodiment, the composition is a solution of uricase. In a preferred embodiment, the solution is sterile and suitable for injection. In one embodiment, such composition comprises uricase as a solution in phosphate buffered saline. In one embodiment, the composition is provided in a vial, optionally having a rubber injection stopper. In particular embodiments, the composition comprises uricase in solution at a concentration of from 2 to 16 milligrams of uricase per milliliter of solution, from 4 to 12 milligrams per milliliter or from 6 to 10 milligrams per milliliter. In a preferred embodiment, the composition comprises uricase at a concentration of 8 milligrams per milliliter. Preferably, the mass of uricase is measured with respect to the protein mass.

[0032] Effective administration regimens of the compositions of the invention may be determined by one of skill in the art. Suitable indicators for assessing effectiveness of a given regimen are known to those of skill in the art. Examples of such indicators include normalization or lowering of plasma uric acid levels (PUA) and lowering or maintenance of PUA to 6.8 mg/dL or less, preferably 6 mg/dL or less. In a preferred embodiment, the subject being treated with the composition of the invention has a PUA of 6 mg/ml or less for at least 70%, at least 80%, or at least 90% of the total treatment period. For example, for a 24 week treatment period, the subject preferably has a PUA of 6 mg/ml or less for at least 80% of the 24 week treatment period, i.e., for at least a time equal to the amount of time in 134.4 days (24 weeks x 7 days/week x 0.8 = 134.4 days).

[0033] In particular embodiments, 0.5 to 24 mg of uricase in solution is administered once every 2 to 4 weeks. The uricase may be administered in any appropriate way known to one of skill in the art, for example, intravenously, intramuscularly or subcutaneously. Preferably, when the administration is intravenous, 0.5 mg to 12 mg of uricase is administered. Preferably, when the administration is subcutaneous, 4 to 24 mg of uricase is administered. In a preferred

embodiment, the uricase is administered by intravenous infusion over a 30 to 240 minute period. In one embodiment, 8 mg of uricase is administered once every two weeks. In particular embodiments, the infusion can be performed using 100 to 500 mL of saline solution. In a preferred embodiment, 8 mg of uricase in solution is administered over a 120 minute period once every 2 weeks or once every 4 weeks; preferably the uricase is dissolved in 250 mL of saline solution for infusion. In particular embodiments, the uricase administrations take place over a treatment period of 3 months, 6 months, 8 months or 12 months. In other embodiments, the treatment period is 12 weeks, 24 weeks, 36 weeks or 48 weeks. In a particular embodiment, the treatment period is for an extended period of time, e.g., 2 years or longer, for up to the life of subject being treated. In addition, multiple treatment periods may be utilized interspersed with times of no treatment, e.g., 6 months of treatment followed by 3 months without treatment, followed by 6 additional months of treatment, etc.

[0034] In certain embodiments, anti-inflammatory compounds may be prophylactically administered to eliminate or reduce the occurrence of infusion reactions due to the administration of uricase. In one embodiment, at least one corticosteroid, at least one antihistamine, at least one NSAID, or combinations thereof are so administered. Useful corticosteroids include betamethasone, budesonide, cortisone, dexamethasone, hydrocortisone, methylprednisolone, prednisolone, prednisone and triamcinolone. Useful NSAIDs include ibuprofen, indomethacin, naproxen, aspirin, acetaminophen, celecoxib and valdecoxib. Useful antihistamines include azatadine, brompheniramine, cetirizine, chlorpheniramine, clemastine, cyproheptadine, desloratadine, dexchlorpheniramine, dimenhydrinate, diphenhydramine, doxylamine, fexofenadine, hydroxyzine, loratadine and phenindamine.

[0035] In a preferred embodiment, the antihistamine is fexofenadine, the NSAID is acetaminophen and the corticosteroid is hydrocortisone and/or prednisone. Preferably, a combination of all three (not necessarily concomitantly) are administered prior to infusion of the

uricase solution. In a preferred embodiment, the NSAID and antihistamine are administered orally 1 to 4 hours prior to uricase infusion. A suitable dose of fexofenadine includes about 30 to about 180 mg, about 40 to about 150 mg, about 50 to about 120 mg, about 60 to about 90 mg, about 60 mg, preferably 60 mg. A suitable dose of acetaminophen includes about 500 to about 1500 mg, about 700 to about 1200 mg, about 800 to about 1100 mg, about 1000 mg, preferably 1000 mg. A suitable dose of hydrocortisone includes about 100 to about 500 mg, about 150 to about 300 mg, about 200 mg, preferably 200 mg. In one embodiment, the antihistamine is not diphenhydramine. In another embodiment, the NSAID is not acetaminophen. In a preferred embodiment, 60 mg fexofenadine is administered orally the night before uricase infusion; 60 mg fexofenadine and 1000 mg of acetaminophen are administered orally the next morning, and finally, 200 mg hydrocortisone is administered just prior to the infusion of the uricase solution. In one embodiment, prednisone is administered the day, preferably in the evening, prior to uricase administration. An appropriate dosage of prednisone includes 5 to 50 mg, preferably 20 mg. In certain embodiments, these prophylactic treatments to eliminate or reduce the occurrence of infusion reactions are utilized for subjects receiving or about to receive uricase, including PEGylated uricase and non-PEGylated uricase. In particular embodiments, these prophylactic treatments are utilized for subjects receiving or about to receive therapeutic peptides other than uricase, wherein the other therapeutic peptides are PEGylated or non-PEGylated.

[0036] In an embodiment of the invention, the pharmaceutical composition comprises a uricase conjugated with a polymer, and the modified uricase retains uricolytic activity. In a preferred embodiment, the uricase is a pegylated uricase.

[0037] In an embodiment of the invention, the pharmaceutical composition comprises a uricase that has been modified by conjugation with a polymer, and the modified uricase retains uricolytic activity. In a particular embodiment, polymer-uricase conjugates are prepared as

described in International Patent Publication No. WO 01/59078, and U.S. Application No. 09/501730, incorporated herein by reference in their entireties.

[0038] In an embodiment of the invention, the polymer is selected from the group comprising polyethylene glycol, dextran, polypropylene glycol, hydroxypropylmethyl cellulose, carboxymethylcellulose, polyvinyl pyrrolidone, and polyvinyl alcohol. In a preferred embodiment, the polymer is polyethylene glycol and the uricase is a PEGylated uricase.

[0039] In embodiments of the invention, the composition comprises 2-12 polymer molecules on each uricase subunit, preferably, 3 to 10 polymer molecules per uricase subunit. In an embodiment of the invention, each polymer molecule has a molecular weight between about 1 kD and about 100 kD.

[0040] In another embodiment of the invention, each polymer molecule has a molecular weight between about 1 kD and about 50 kD. In a preferred embodiment of the invention, each polymer molecule has a molecular weight of between about 5 kD and about 20 kD, about 8 kD and about 15 kD, about 10 kD and 12 kD, preferably about 10 kD. In a preferred embodiment, each polymer molecule has a molecular weight of about 5 kD or about 20 kD. In an especially preferred embodiment of the invention, each polymer molecule has a molecular weight of 10 kD.

[0041] In an embodiment of the invention, the composition is suitable for repeated administration of the composition.

[0042] The subject invention provides a means for metabolizing uric acid using the uricase.

[0043] The subject invention provides a use of a composition of uricase for reducing uric acid levels in a biological fluid.

[0044] In an embodiment of the invention, the composition of uricase is used for reducing uric acid in a biological fluid comprising blood.

[0045] Also provided are novel nucleic acid molecules encoding the uricase of the invention.

The manipulations which result in their production are well known to the one of skill in the art.

For example, uricase nucleic acid sequences can be modified by any of numerous strategies known in the art (Maniatis, T., 1990, *Molecular Cloning, A Laboratory Manual*, 2d ed., Cold Spring Harbor Laboratory, Cold Spring Harbor, N.Y.). The sequence can be cleaved at appropriate sites with restriction endonuclease(s), followed by further enzymatic modification if
5 desired, isolated, and ligated in vitro. In the production of the gene encoding a uricase, care should be taken to ensure that the modified gene remains within the appropriate translational reading frame, uninterrupted by translational stop signals.

[0046] The nucleotide sequence coding for a uricase protein can be inserted into an appropriate expression vector, i.e., a vector which contains the necessary elements for the
10 transcription and translation of the inserted protein-coding sequence. A variety of host-vector systems may be utilized to express the protein-coding sequence. These include but are not limited to mammalian cell systems infected with virus (e.g., vaccinia virus, adenovirus, etc.); insect cell systems infected with virus (e.g., baculovirus); microorganisms such as yeast containing yeast vectors, or bacteria transformed with bacteriophage DNA, plasmid DNA, or
15 cosmid DNA. The expression elements of these vectors vary in their strengths and specificities. Depending on the host-vector system utilized, any one of a number of suitable transcription and translation elements may be used.

[0047] Any of the methods known for the insertion of DNA fragments into a vector may be used to construct expression vectors containing a chimeric gene consisting of appropriate
20 transcriptional/translational control signals and the protein coding sequences. These methods may include in vitro recombinant DNA and synthetic techniques and in vivo recombinations (genetic recombination). Expression of nucleic acid sequence encoding uricase protein may be regulated by a second nucleic acid sequence so that uricase protein is expressed in a host transformed with the recombinant DNA molecule. For example, expression of uricase may be
25 controlled by any promoter/enhancer element known in the art. Promoters which may be used to

control uricase expression include, but are not limited to, the SV40 early promoter region (Bernoist and Chambon, 1981, Nature 290:304-310), the promoter contained in the 3' long terminal repeat of Rous sarcoma virus (Yamamoto, et al., 1980, Cell 22:787-797), the herpes thymidine kinase promoter (Wagner et al., 1981, Proc. Natl. Acad. Sci. U.S.A. 78:144-1445), the regulatory sequences of the metallothionine gene (Brinster et al., 1982, Nature 296:39-42); prokaryotic expression vectors such as the β -lactamase promoter (Villa-Kamaroff, et al., 1978, Proc. Natl. Acad. Sci. U.S.A. 75:3727-3731), the tac promoter (DeBoer, et al., 1983, Proc. Natl. Acad. Sci. U.S.A. 80:21-25), and the osmB promoter. In particular embodiments, the nucleic acid comprises a nucleic acid sequence encoding the uricase operatively linked to a heterologous promoter.

[0048] Once a particular recombinant DNA molecule comprising a nucleic acid sequence encoding is prepared and isolated, several methods known in the art may be used to propagate it. Once a suitable host system and growth conditions are established, recombinant expression vectors can be propagated and prepared in quantity. As previously explained, the expression vectors which can be used include, but are not limited to, the following vectors or their derivatives: human or animal viruses such as vaccinia virus or adenovirus; insect viruses such as baculovirus; yeast vectors; bacteriophage vectors (e.g., lambda), and plasmid and cosmid DNA vectors, to name but a few.

[0049] In addition, a host cell strain may be chosen which modulates the expression of the inserted sequences, or modifies and processes the gene product in the specific fashion desired. Expression from certain promoters can be elevated in the presence of certain inducers; thus, expression of the genetically engineered uricase protein may be controlled. Furthermore, different host cells have characteristic and specific mechanisms for the translational and post-translational processing and modification (e.g., glycosylation, cleavage) of proteins. Appropriate cell lines or host systems can be chosen to ensure the desired modification and processing of the

foreign protein expressed. Different vector/host expression systems may effect processing reactions such as proteolytic cleavages to different extents.

[0050] In particular embodiments of the invention expression of uricase in E. coli is preferably performed using vectors which comprise the osmB promoter.

5 **EXAMPLES**

Example 1. Construction Of Gene And Expression Plasmid For Uricase Expression

[0100] Recombinant porcine uricase (urate oxidase), Pig-KS-ΔN (amino terminus truncated pig uricase protein replacing amino acids 291 and 301 with lysine and serine, respectively) was expressed in E. coli K-12 strain W3110 F-. A series of plasmids was constructed culminating in
10 pOUR-P-ΔN-ks-1, which upon transformation of the E. coli host cells was capable of directing efficient expression of uricase.

Isolation And Subcloning Of Uricase cDNA From Pig And Baboon Liver

[0101] Uricase cDNAs were prepared from pig and baboon livers by isolation and subcloning of the relevant RNA. Total cellular RNA was extracted from pig and baboon livers
15 (Erlich, H. A. (1989). PCR Technology; Principles and Application for DNA Amplification; Sambrook, J., et al. (1989). Molecular Cloning: A Laboratory Manual, 2nd edition; Ausubel, F. M. et al. (1998). Current protocols in molecular Biology), then reverse-transcribed using the First-Strand cDNA Synthesis Kit (Pharmacia Biotech). PCR amplification was performed using Taq DNA polymerase (Gibco BRL, Life Technologies).

20 **[0102]** The synthetic oligonucleotide primers used for PCR amplification of pig and baboon urate oxidases (uricase) are shown in Table 1.

Table 1. Primers For PCR Amplification Of Uricase cDNA

<u>Pig liver uricase:</u>	
sense	5' gcgcgaattccATGGCTCATTACCGTAATGACTACA 3'
(SEQ ID NO. 1)	
anti-sense	5' gcgctctagaagcttccatggTCACAGCCTTGAAGTCAGC 3'
(SEQ ID NO. 2)	
<u>Baboon (D3H) liver uricase:</u>	
sense	5' gcgcgaattccATGGCCCACTACCATAACA ACTAT 3'
(SEQ ID NO. 3)	
anti-sense	5' gcgcccattggtctagaTCACAGTCTTGAAGACA ACTTCCT 3'
(SEQ ID NO. 4)	

[0103] Restriction enzyme sequences, introduced at the ends of the primers and shown in lowercase in Table 1, were sense EcoRI and NcoI (pig and baboon) and anti-sense NcoI, HindIII and XbaI (pig), XbaI and NcoI (baboon). In the baboon sense primer, the third codon GAC (aspartic acid) present in baboon uricase was replaced with CAC (histidine), the codon that is present at this position in the coding sequence of the human urate oxidase pseudogene. The recombinant baboon uricase construct generated using these primers is named D3H Baboon Uricase.

[0104] The pig uricase PCR product was digested with EcoRI and HindIII and cloned into pUC18 to create pUC18 – Pig Uricase. The D3H Baboon Uricase PCR product was cloned directly into pCRTMII vector, using TA CloningTM (Invitrogen, Carlsbad, CA), creating pCRTMII –D3H Baboon Uricase.

[0105] Ligated cDNAs were used to transform *E. coli* strain XL1-Blue (Stratagene, La Jolla, CA). Plasmid DNA containing cloned uricase cDNA was prepared, and clones which possess the

published uricase DNA coding sequences (except for the D3H substitution in baboon uricase, shown in Table 1) were selected and isolated. In the pCRTMII - D3H Baboon Uricase clone chosen, the pCRTMII sequences were next to the uricase stop codon, resulting from deletion of sequences introduced by PCR. As a consequence, the XbaI and NcoI restriction sites from the 3' untranslated region were eliminated, thus allowing directional cloning using NcoI at the 5' end of the PCR product and BamHI which is derived from the pCRTMII vector.

Subcloning Of Uricase cDNA Into pET Expression Vectors

Baboon Uricase Subcloning

[0106] The D3H baboon cDNA containing full length uricase coding sequence was introduced into pET-3d expression vector (Novagen, Madison, WI). The pCRTMII - D3H Baboon Uricase was digested with NcoI and BamHI, and the 960 bp fragment was isolated. The expression plasmid pET-3d was digested with NcoI and BamHI, and the 4600 bp fragment was isolated. The two fragments were ligated to create pET-3d-D3H-Baboon.

Pig-Baboon Chimera Uricase Subcloning

[0107] Pig-baboon chimera (PBC) uricase was constructed in order to gain higher expression, stability, and activity of the recombinant gene. PBC was constructed by isolating the 4936 bp NcoI-ApaI fragment from pET-3d-D3H-Baboon clone and ligating the isolated fragment with the 624 bp NcoI-ApaI fragment isolated from pUC18 -Pig Uricase, resulting in the formation of pET-3d-PBC. The PBC uricase cDNA consists of the pig uricase codons 1-225 joined in-frame to codons 226-304 of baboon uricase.

Pig-KS Uricase Subcloning

[0108] Pig-KS uricase was constructed in order to add one lysine residue, which may provide an additional PEGylation site. KS refers to the amino acid insert of lysine into pig uricase, at position 291, in place of arginine (R291K). In addition, the threonine at position 301 was replaced with serine (T301S). The PigKS uricase plasmid was constructed by isolating the

4696 bp NcoI-NdeI fragment of pET-3d-D3H-Baboon, and then it was ligated with the 864 bp NcoI-NdeI fragment isolated from pUC18 - Pig Uricase, resulting in the formation of pET-3d-PigKS. The resulting PigKS uricase sequence consists of the pig uricase codons 1-288 joined in-frame to codons 289-304 of baboon uricase.

5 **Subcloning Of Uricase Sequence Under The Regulation Of The *osmB* Promoter**

[0109] The uricase gene was subcloned into an expression vector containing the *osmB* promoter (following the teaching of Unites States Patent No. 5,795,776, incorporated herein by reference in its entirety). This vector enabled induction of protein expression in response to high osmotic pressure or culture aging. The expression plasmid pMFOA-18 contained the *osmB* promoter, a ribosomal binding site sequence (rbs) and a transcription terminator sequence (ter). It confers ampicillin resistance (AmpR) and expresses the recombinant human acetylcholine esterase (AChE).

Subcloning Of D3H-Baboon Uricase

[0110] The plasmid pMFOA-18 was digested with NcoI and BamHI, and the large fragment was isolated. The construct pET-3d-D3H-Baboon was digested with NcoI and BamHI and the 960 bp fragment, which included the D3H Baboon Uricase gene is isolated. These two fragments were ligated to create pMFOU18.

[0111] The expression plasmid pMFXT133 contained the *osmB* promoter, a rbs (*E. coli* deo operon), ter (*E. coli* TrypA), the recombinant factor Xa inhibitor polypeptide (FxaI), and it conferred the tetracycline resistance gene (TetR). The baboon uricase gene was inserted into this plasmid in order to exchange the antibiotic resistance genes. The plasmid pMFOU18 was digested with NcoI, filled-in, then it was digested with XhoI, and a 1030 bp fragment was isolated. The plasmid pMFXT133 was digested with NdeI, filled-in, then it was digested with XhoI, and the large fragment was isolated. The two fragments were ligated to create the baboon uricase expression vector, pURBA16.

Subcloning Of The Pig Baboon Chimera Uricase

[0112] The plasmid pURBA16 was digested with ApaI and AlwNI, and the 2320 bp fragment was isolated. The plasmid pMFXT133 was digested with NdeI, filled-in, then it was digested with AlwNI, and the 620 bp fragment was isolated. The construct pET-3d-PBC was digested with XbaI, filled-in, then it was digested with ApaI, and the 710 bp fragment was isolated. The three fragments were ligated to create pUR-PB, a plasmid that expressed PBC uricase under the control of osmB promoter and rbs as well as the T7 rbs, which was derived from the pET-3d vector.

[0113] The T7 rbs was excised in an additional step. pUR-PB was digested with NcoI, filled-in, then digested with AlwNI, and the 3000 bp fragment was isolated. The plasmid pMFXT133 was digested with NdeI, filled in and then digested with AlwNI, and the 620 bp fragment was isolated. The two fragments were ligated to form pDUR-PB, which expresses PBC under the control of the osmB promoter.

Construction Of pOUR-PB-ANC

[0114] Several changes were introduced into the uricase cDNA, which resulted in a substantial increase in the recombinant enzyme stability. Plasmid pOUR-PBC-ANC was constructed, in which the N-terminal six-residue maturation peptide and the tri-peptide at the C-terminus, which function *in vivo* as peroxysomal targeting signal, were both removed. This was carried out by utilizing PBC sequence in plasmid pDUR-PB and the specific oligonucleotide primers listed in Table 2, using PCR amplification.

Table 2. Primers for PCR Amplification of PBC-ANC Uricase

PBC-ANC Uricase:	
Sense	
5' gcgcatATGACTTACAAAAAGAATGATGAGGTAGAG 3' (SEQ ID NO. 5)	
Anti-sense	

5' **ccgtctaga**TTAAGACAACCTTCCTCTTGACTGTACCAGTAATTTTCCGTATGG 3'
(SEQ ID NO. 6)

[0115] The restriction enzyme sequences introduced at the ends of the primers shown in bold and the non-coding regions are shown in lowercase in Table 2. NdeI is sense and XbaI is anti-sense. The anti-sense primer was also used to eliminate an internal NdeI restriction site by introducing a point mutation (underlined) which did not affect the amino acid sequence, and thus, facilitated subcloning by using NdeI.

[0116] The 900 base-pair fragment generated by PCR amplification of pDUR-PB was cleaved with NdeI and XbaI and isolated. The obtained fragment was then inserted into a deo expression plasmid pDBAST-RAT-N, which harbors the deo-P1P2 promoter and rbs derived from *E. coli* and constitutively expresses human recombinant insulin precursor. The plasmid was digested with NdeI and XbaI and the 4035 bp fragment was isolated and ligated to the PBC-uricase PCR product. The resulting construct, pDUR-PB- Δ NC, was used to transform *E. coli* K-12 S ϕ 733 (F- cytR strA) that expressed a high level of active truncated uricase.

[0117] The doubly truncated PBC- Δ NC sequence was also expressed under the control of osmB promoter. The plasmid pDUR-PB- Δ NC was digested with AlwNI – NdeI, and the 3459 bp fragment was isolated. The plasmid pMFXT133, described above, was digested with NdeI – AlwNI, and the 660 bp fragment was isolated. The fragments were then ligated to create pOUR-PB- Δ NC, which was introduced into *E. coli* K-12 strain W3110 F⁻ and expressed high level of active truncated uricase.

Construction Of The Uricase Expression Plasmid pOUR-P- Δ N-ks-1

[0118] This plasmid was constructed in order to improve the activity and stability of the recombinant enzyme. Pig-KS- Δ N uricase was truncated at the N-terminus only (Δ N), where the six-residue N-terminal maturation peptide was removed, and contained the mutations S46T,

R291K and T301S. At position 46, there was a threonine residue instead of serine due to a conservative mutation that occurred during PCR amplification and cloning. At position 291, lysine replaced arginine, and at position 301, serine was inserted instead of threonine. Both were derived from the baboon uricase sequence. The modifications of R291K and T301S are designated KS, and discussed above. The extra lysine residue provided an additional potential PEGylation site.

[0119] To construct pOUR-P- Δ N-ks-1 (Figure 1), the plasmid pOUR-PB- Δ NC was digested with ApaI – XbaI, and the 3873 bp fragment was isolated. The plasmid pET-3d-PKS (construction shown in Figure 4) was digested with ApaI – SpeI, and the 270 bp fragment was isolated. SpeI cleavage left a 5' CTAG extension that was efficiently ligated to DNA fragments generated by XbaI. The two fragments were ligated to create pOUR-P- Δ N-ks-1. After ligation, the SpeI and XbaI recognition sites were lost (their site is shown in parenthesis in Figure 9). The construct pOUR-P- Δ N-ks-1 was introduced into *E. coli* K-12 strain W3110 F⁻, prototrophic, ATCC # 27325. The resulting Pig-KS- Δ N uricase, expressed under the control of osmB promoter, yielded high levels of recombinant enzyme having superior activity and stability.

[0120] Figure 1 illustrates the structure of plasmid pOUR-P- Δ N-ks-1. Numbers next to restriction sites indicate nucleotide position, relative to HaeII site, designated as 1; restriction sites that were lost during cloning are marked in parenthesis. Plasmid pOUR-P- Δ N-ks-1, encoding Pig-KS- Δ N uricase is 4143 base pairs (bp) long and comprised the following elements:

1. A DNA fragment, 113 bp long, spanning from nucleotide number 1 to NdeI site (at position 113), which includes the osmB promoter and ribosome binding site (rbs).
2. A DNA fragment, 932 bp long, spanning from NdeI (at position 113) to SpeI/XbaI junction (at position 1045), which includes: 900 bp of Pig-KS- Δ N (nucleic acid sequence of amino terminus truncated pig uricase protein in which

amino acids 291 and 301 with lysine and serine, respectively, are replaced) coding region and 32 bp flanking sequence derived from pCRTM II, from the TA cloning site upstream to the SpeI/XbaI restriction site.

3. A 25 bp multiple cloning sites sequence (MCS) from SpeI/XbaI junction (at position 1045) to HindIII (at position 1070).
4. A synthetic 40 bp oligonucleotide containing the TrpA transcription terminator (ter) with HindIII (at position 1070) and AatII (at position 1110) ends.
5. A DNA fragment, 1519 bp long, spanning from AatII (at position 1110) to MscI/ScaI (at position 2629) sites on pBR322 that includes the tetracycline resistance gene (TetR).
6. A DNA fragment, 1514 bp long, spanning from ScaI (at position 2629) to HaeII (at position 4143) sites on pBR322 that includes the origin of DNA replication.

[0121] Figure 2 shows the DNA and the deduced amino acid sequences of Pig-KS-ΔN uricase. In this figure, the amino acid numbering is according to the complete pig uricase sequence. Following the initiator methionine residue, a threonine was inserted in place of the aspartic acid of the pig uricase sequence. This threonine residue enabled the removal of methionine by bacterial aminopeptidase. The gap in the amino acid sequence illustrates the deleted N-terminal maturation peptide. The restriction sites that were used for the various steps of subcloning of the different uricase sequences (ApaI, NdeI, BamHI, EcoRI and SpeI) are indicated. The 3' untranslated sequence, shown in lowercase letters, was derived from pCRTM II sequence. The translation stop codon is indicated by an asterisk.

[0122] Figure 3 shows alignment of the amino acid sequences of the various recombinant uricase sequences. The upper line represents the pig uricase, which included the full amino acid sequence. The second line is the sequence of the doubly truncated pig-baboon chimera uricase (PBC-ΔNC). The third line shows the sequence of Pig-KS-ΔN uricase, that is only truncated at

the N-terminus and contained the mutations S46T and the amino acid changes R291K and T301S, both reflecting the baboon origin of the carboxy terminus of the uricase coding sequence. The asterisks indicate the positions in which there are differences in amino acids in the Pig-KS- Δ N as compared to the published pig uricase sequence; the circles indicate positions in which there are differences in amino acids in Pig-KS- Δ N compared to PBC- Δ N, the pig-baboon chimera; and dashed lines indicate deletion of amino acids.

[0123] cDNA for native baboon, pig, and rabbit uricase with the Y97H mutation, and the pig/baboon chimera (PBC) were constructed for cloning into *E. coli*. Clones expressing high levels of the uricase variants were constructed and selected such that all are W3110 F⁻ *E. coli*, and expression is regulated by *osmB*. Plasmid DNAs were isolated, verified by DNA sequencing and restriction enzyme analysis, and cells were cultured.

[0124] Construction of the truncated uricases, including pig- Δ N and Pig-KS- Δ N was done by cross-ligation between PBC- Δ NC and Pig-KS, following cleavage with restriction endonucleases *ApaI* and *XbaI*, and *ApaI* plus *SpeI*, respectively. It is reasonable that these truncated mutants would retain activity, since the N-terminal six residues, the “maturation peptide” (1-2), and the C-terminal tri-peptide, “peroxisomal targeting signal” (3-5), do not have functions which significantly affect enzymatic activity, and it is possible that these sequences may be immunogenic. Clones expressing very high levels of the uricase variants were selected.

Example 2. Transformation Of The Expression Plasmid Into A Bacterial Host Cell

[0125] The expression plasmid, pOUR-P- Δ N-ks-1, was introduced into *E. coli* K-12 strain W3110 F⁻. Bacterial cells were prepared for transformation involved growth to mid log phase in Luria broth (LB), then cells were harvested by centrifugation, washed in cold water, and suspended in 10% glycerol, in water, at a concentration of about 3×10^{10} cells per ml. The cells were stored in aliquots, at -70°C. Plasmid DNA was precipitated in ethanol and dissolved in water.

[0126] Bacterial cells and plasmid DNA were mixed, and transformation was done by the high voltage electroporation method using Gene Pulser II from BIO-RAD (Trevors et al (1992). Electrotransformation of bacteria by plasmid DNA, in Guide to Electroporation and Electrofusion (D.C. Chang, B. M. Chassy, J. A. Saunders and A. E. Sowers, eds.), pp. 265-290, Academic Press Inc., San Diego, Hanahan et al (1991) Meth. Enzymol., 204, 63-113). Transformed cells were suspended in SOC medium (2% tryptone, 0.5% yeast extract, 10 mM NaCl, 2.5mM KCl, 10 mM MgCl₂, 10 mM MgSO₄, 20 mM glucose), incubated, at 37°C, for 1 hour and selected for tetracycline resistance. A high expresser clone was selected.

Example 3. Recombinant Uricase Preparation

[0127] Bacteria such as those transformed (see above) were cultured in medium containing glucose; pH was maintained at 7.2 ± 0.2 , at approximately 37°C.

[0128] Towards the last 5-6 hours of cultivation, the medium was supplemented with KCl to a final concentration of 0.3M. Cultivation was continued to allow uricase accumulation.

[0129] Recombinant uricase accumulated within bacterial cells as an insoluble precipitate similar to inclusion bodies (IBs). The cell suspension was washed by centrifugation and suspended in 50 mM Tris buffer, pH 8.0 and 10 mM EDTA and brought to a final volume of approximately 40 times the dry cell weight.

[0130] Recombinant uricase-containing IBs, were isolated by centrifugation following disruption of bacterial cells using lysozyme and high pressure. Treatment with lysozyme (2000-3000 units/ml) was done for 16-20 hours at pH 8.0 and $7 \pm 3^\circ\text{C}$, while mixing. The pellet was washed with water and stored at -20°C until use.

[0131] The enriched IBs were further processed after suspending in 50 mM NaHCO₃ buffer, pH 10.3 ± 0.1 . The suspension was incubated overnight, at room temperature, to allow solubilization of the IB-derived uricase, and subsequently clarified by centrifugation.

[0132] Uricase was further purified by several chromatography steps. Initially, chromatography was done on a Q-Sepharose FF column. The loaded column was washed with bicarbonate buffer containing 150 mM NaCl, and uricase was eluted with bicarbonate buffer, containing 250 mM NaCl. Then, Xanthine-agarose resin (Sigma) was used to remove minor impurities from the uricase preparation. The Q-Sepharose FF eluate was diluted with 50 mM glycine buffer, pH 10.3±0.1, to a protein concentration of approximately 0.25 mg/ml and loaded. The column was washed with bicarbonate buffer, pH 10.3±0.1, containing 100 mM NaCl, and uricase was eluted with the same buffer supplemented with 60 µM xanthine. At this stage, the uricase was repurified by Q-Sepharose chromatography to remove aggregated forms.

[0133] The purity of each uricase preparation is greater than 95%, as determined by size exclusion chromatography. Less than 0.5% aggregated forms are detected in each preparation using a Superdex 200 column.

[0134] Table 3 summarizes purification of Pig-KSΔN uricase from IBs derived from 25 L fermentation broth.

Table 3. Purification Of Pig-KSΔN Uricase

Purification step	Protein (mg)	Activity (U)	Specific Activity (U/mg)
IB dissolution	12,748	47,226	3.7
Clarified solution	11,045	44,858	4.1
Q-Sepharose I - main pool	7,590	32,316	4.3
Xanthine Agarose - main pool	4,860	26,361	5.4
Q-Sepahrose II – main pool	4,438	22,982	5.2
30 kD UF retentate	4,262	27,556	6.5

Example 4. Characteristics Of Recombinant Uricases

SDS-PAGE

[0135] SDS-PAGE analysis of the highly purified uricase variants (Figure 4) revealed a rather distinctive pattern. The samples were stored at 4°C, in carbonate buffer, pH 10.3, for up to several months. The full-length variants, Pig, Pig-KS, and PBC, show accumulation of two

major degradation products having molecular weights of about 20 and 15kD. This observation suggests that at least a single nick split the uricase subunit molecule. A different degradation pattern is detected in the amino terminal shortened clones and also in the rabbit uricase, but at a lower proportion. The amino terminus of the rabbit resembles that of the shortened clones. The amino terminal sequences of the uricase fragments generated during purification and storage were determined.

Peptide Sequencing

[0136] N-terminal sequencing of bulk uricase preparations was done using the Edman degradation method. Ten cycles were performed. Recombinant Pig uricase (full length clone) generated a greater abundance of degradation fragments compared to Pig-KS-ΔN. The deduced sites of cleavage leading to the degradation fragments are as follows:

1) Major site at position 168 having the sequence:

--QSG ↓ FEGFI--

2) Minor site at position 142 having the sequence:

--IRN ↓ GPPVI--

[0137] The above sequences do not suggest any known proteolytic cleavage. Nevertheless, cleavage could arise from either proteolysis or some chemical reaction. The amino-truncated uricases are surprisingly more stable than the non-amino truncated uricases. PBC-ΔNC also had stability similar to the other ΔN molecules and less than non-amino-truncated PBC.

Potency

[0138] Activity of uricase was measured by a UV method. Enzymatic reaction rate was determined by measuring the decrease in absorbance at 292 nm resulting from the oxidation of uric acid to allantoin. One activity unit is defined as the quantity of uricase required to oxidize one μmole of uric acid per minute, at 25°C, at the specified conditions. Uricase potency is expressed in activity units per mg protein (U/mg).

[0139] The extinction coefficient of 1 mM uric acid at 292 nm is $12.2 \text{ mM}^{-1} \text{ cm}^{-1}$. Therefore, oxidation of 1 μmole of uric acid per ml reaction mixture resulted in a decrease in absorbance of 12.2 mA_{292} . The absorbance change with time (ΔA_{292} per minute) was derived from the linear portion of the curve.

5 [0140] Protein concentration was determined using a modified Bradford method (Macart and Gerbaut (1982) Clin Chim Acta 122:93-101). The specific activity (potency) of uricase was calculated by dividing the activity in U/ml with protein concentration in mg/ml. The enzymatic activity results of the various recombinant uricases are summarized in Table 4. The results of commercial preparations are included in this table as reference values. It is apparent from these
10 results that truncation of uricase proteins has no significant effect on their enzymatic activity.

Table 4. Summary of Kinetic Parameters of Recombinant and Native Uricases

Uricases	Concentration ⁽¹⁾ of Stock(mg/ml)	Specific Activity (U/mg) ⁽²⁾	Km ⁽⁴⁾ (μM Uric Acid)	Kcat ⁽⁵⁾ (1/min)
Recombinant				
Pig	0.49	7.41	4.39	905
Pig-ΔN	0.54	7.68	4.04	822
Pig-KS	0.33	7.16	5.27	1085
Pig-KS-ΔN	1.14	6.20	3.98	972
PBC	0.76	3.86	4.87	662
PBC-ΔNC	0.55	3.85	4.3	580
Rabbit	0.44	3.07	4.14	522
Native				
Pig (Sigma)	2.70	3.26 ⁽³⁾	5.85	901
A. flavus (Merck)	1.95	0.97 ⁽³⁾	23.54	671

[0141] Table 4 Notes:

(1) Protein concentration was determined by absorbance measured at 278 nm, using an Extinction coefficient of 11.3 for a 10 mg/ml uricase solution (Mahler, 1963).

(2) 1 unit of uricase activity is defined as the amount of enzyme that oxidizes 1 μmole of uric acid to allantoin per minute, at 25°C.

(3) Specific activity values were derived from the Lineweaver-Burk plots, at a concentration of substrate equivalent to 60 μM.

(4) Reaction Mixtures were composed of various combinations of the following stock solutions

100 mM sodium borate buffer, pH 9.2

300 μM Uric acid in 50 mM sodium borate buffer, pH 9.2

1 mg/ml BSA in 50 mM sodium borate buffer, pH 9.2

(5) K_{cat} was calculated by dividing the V_{max} (calculated from the respective Lineweaver-Burk plots) by the concentration of uricase in reaction mixture (expressed in mol equivalents, based on the tetrameric molecular weights of the uricases).

Example 5. Conjugation Of Uricase With m-PEG (PEGylation)

[0142] Pig-KS-ΔN Uricase was conjugated using m-PEG-NPC (monomethoxy-poly(ethylene glycol)-nitrophenyl carbonate). Conditions resulting in 2 - 12 strands of 5, 10, or 20 kD PEG per uricase subunit were established. m-PEG-NPC was gradually added to the protein solution. After PEG addition was concluded, the uricase / m-PEG-NPC reaction mixture was then incubated at 2-8°C for 16-18 hours, until maximal unbound m-PEG strands were conjugated to uricase.

[0143] The number of PEG strands per PEG-uricase monomer was determined by Superose 6 size exclusion chromatography (SEC), using PEG and uricase standards. The number of bound PEG strands per subunit was determined by the following equation:

$$\text{PEG strands/subunit} = \frac{3.42 \times \text{Amount of PEG in injected sample } (\mu\text{g})}{\text{Amount of protein in injected sample } (\mu\text{g})}$$

[0144] The concentration of PEG and protein moieties in the PEG-uricase sample was determined by size exclusion chromatography (SEC) using ultraviolet (UV) and refractive index (RI) detectors arranged in series (as developed by Kunitani, et al., 1991). Three calibration curves are generated: a protein curve (absorption measured at 220 nm); a protein curve (measured by RI); and PEG curve (measured by RI). Then, the PEG-uricase samples were analyzed using the same system. The resulting UV and RI peak area values of the experimental samples were used to calculate the concentrations of the PEG and protein relative to the calibration curves. The index of 3.42 is the ratio between the molecular weight of uricase monomer (34,192 Daltons) to that of the 10 kD PEG.

[0145] Attached PEG improved the solubility of uricase in solutions having physiological pH values. Table 5 provides an indication of the variability between batches of PEGylated Pig-KS-ΔN uricase product. In general, there is an inverse relation between the number of PEG strands attached and retained specific activity (SA) of the enzyme.

Table 5. Enzymatic Activity Of PEGylated Pig-KS-ΔN Uricase Conjugates

Conjugate Batches	PEG MW (kD)	PEG Strands per Uricase Subunit	Uricase SA (U/mg)	SA Percent of Control
ΔN-Pig-KS	-	-	8.2	100
1-17 #	5	9.7	5.8	70.4
LP-17	10	2.3	7.8	94.6
1-15 #	10	5.1	6.4	77.9
13 #	10	6.4	6.3	76.9
14 #	10	6.5	6.4	77.5
5-15 #	10	8.8	5.4	65.3
5-17 #	10	11.3	4.5	55.3
4-17 #	10	11.8	4.4	53.9
1-18 #	20	11.5	4.5	54.4

Example 6. PEGylation of uricase with 1000 D and 100,000 D PEG

5 [0146] Pig-KS-ΔN Uricase was conjugated using 1000 D and 100,000 D m-PEG-NPC as described in Example 5. Conditions resulting in 2 - 11 strands of PEG per uricase subunit were used. After PEG addition was concluded, the uricase/m-PEG-NPC reaction mixture was then incubated at 2-8°C for 16-18 hours, until maximal unbound m-PEG strands were conjugated to uricase.

10 [0147] The number of PEG strands per PEG-uricase monomer was determined as described above.

[0148] Attached PEG improved the solubility of uricase in solutions having physiological pH values.

Example 7. Pharmacokinetics Of Pig-KS-ΔN Uricase Conjugated With PEG

15 [0149] Biological experiments were undertaken in order to determine the optimal extent and size of PEGylation needed to provide therapeutic benefit.

[0150] Pharmacokinetic studies in rats, using i.v. injections of 0.4 mg (2U) per kg body weight of unmodified uricase, administered at day 1 and day 8, yielded a circulating half life of about 10 minutes. However, studies of the clearance rate in rats with 2-11x10kD PEG-Pig-KS-

Δ N uricase, after as many as 9 weekly injections, indicated that clearance did not depend on the number of PEG strands (within this range) and remained relatively constant throughout the study period (see Table 6; with a half-life of about 30 hours). The week-to-week differences are within experimental error. This same pattern is apparent after nine injections of the 10x5kD PEG, and 10x20kD PEG – uricase conjugates. The results indicated that regardless of the extent of uricase PEGylation, in this range, similar biological effects were observed in the rat model.

Table 6. Half Lives of PEGylated Pig-KS- Δ N Uricase Preparations in Rats

Week	Extent of Modification (PEG Strands per Uricase Subunit)						
	5kDPEG	10kD PEG					20kD PEG
	10x	2x	5x	7x	9x	11x	10x
1	25.7 ± 1.7 (5)	29.4 ± 3.4 (5)	37.7 ± 3.1 (5)	37.6 ± 3.9 (5)	36.9 ± 4.3 (5)	31.4 ± 4.3 (5)	21.6 ± 1.5 (5)
2	-	-	-	26.7 ± 3.0 (5)	28.4 $\pm$ 1.6 (5)	-	-
3	27.5 ± 3.8 (5)	29.0 ± 2.6 (5)	29.9 ± 11.7 (5)	32.7 ± 11.1 (5)	26.3 ± 4.7 (5)	11.8 ± 3.3 (5)	14.5 ± 2.7 (5)
4	-	-	27.1 ± 5.3 (5)	18.4 ± 2.2 (4)	19.7 ± 5.6 (4)	-	-
5	28.6 ± 1.7 (5)	22.5 ± 2.7 (5)	34.3 ± 3.9 (4)	37.3 ± 3.0 (5)	30.4 ± 3.6 (5)	30.5 ± 1.3 (5)	19.3 ± 2.5 (5)
6	-	-	35.4 ± 3.1 (14)	27.1 ± 3.6 (13)	30.7 ± 2.9 (13)	-	-
7	16.5 ± 4.9 (5)	32.5 ± 4.3 (5)	-	-	-	16.12 ± 2.7 (5)	25.8 ± 2.5 (5)
8	-	-	-	-	-	-	-
9	36.8 ± 4.0 (15)	28.7 ± 2.7 (15)	34.0 ± 2.4 (13)	24.2 ± 3.4 (13)	31.0 ± 2.6 (13)	29.3 ± 1.4 (15)	26.7 ± 0.5 (15)

[0151] Table 6 notes: Results are indicated in hours $\pm$ standard error of the mean. Numbers

10 in parenthesis indicate the number of animals tested.

[0152] Rats received weekly i.v. injections of 0.4 mg per kilogram body weight of Pig-KS- Δ N uricase modified as indicated in the table. Each group initially comprised 15 rats, which were alternately bled in subgroups of 5. Several rats died during the study due to the anesthesia. Half-lives were determined by measuring uricase activity (colorimetric assay) in plasma samples collected at 5 minutes, and 6, 24 and 48 hours post injection.

[0153] Table 5 describes the batches of PEGylated uricase used in the study.

[0154] Bioavailability studies with 6x5 kD PEG- Pig-KS- Δ N uricase in rabbits indicate that, after the first injection, the circulation half-life is 98.2 ± 1.8 hours (i.v.), and the bioavailability after i.m. and subcutaneous (s.c.) injections was 71% and 52%, respectively. However, significant anti-uricase antibody titers were detected, after the second i.m. and s.c. injections, in all of the rabbits, and clearance was accelerated following subsequent injections. Injections of rats with the same conjugate resulted in a half-life of 26 ± 1.6 hours (i.v.), and the bioavailability after i.m. and s.c. injections was 33% and 22%, respectively.

[0155] Studies in rats, with 9x10 kD PEG- Pig-KS- Δ N uricase indicate that the circulation half-life after the first injection is 42.4 hours (i.v.), and the bioavailability, after i.m. and s.c. injections, was 28.9% and 14.5%, respectively (see Figure 5 and Table 7). After the fourth injection, the circulation half-life was 32.1 ± 2.4 hours and the bioavailability, after the i.m. and s.c. injections was 26.1% and 14.9%, respectively.

[0156] Similar pharmacokinetic studies, in rabbits, with 9x10 kD PEG-Pig-KS- Δ N uricase indicate that no accelerated clearance was observed following injection of this conjugate (4 biweekly injections were administered). In these animals, the circulation half-life after the first injection was 88.5 hours (i.v.), and the bioavailability, after i.m. and s.c. injections, was 98.3% and 84.4%, respectively (see Figure 6 and Table 7). After the fourth injection the circulation half-life was 141.1 ± 15.4 hours and the bioavailability, after the i.m. and s.c. injections was 85% and 83%, respectively.

[0157] Similar studies with 9x10 kD PEG-Pig-KS-ΔN were done to assess the bioavailability in beagles (2 males and 2 females in each group). A circulation half-life of 70±11.7 hours was recorded after the first i.v. injection, and the bioavailability, after the i.m. and s.c. injections was 69.5% and 50.4%, respectively (see Figure 7 and Table 7).

5 **[0158]** Studies with 9x10 kD PEG-Pig-KS-ΔN preparations were done using pigs. Three animals per group were used for administration via the i.v., s.c. and i.m. routes. A circulation half-life of 178±24 hours was recorded after the first i.v. injection, and the bioavailability, after the i.m. and s.c. injections was 71.6% and 76.8%, respectively (see Figure 8 and Table 7).

Table 7. Pharmacokinetic Studies with 9x10 kD PEG-Pig-KS-ΔN Uricase

Injection #	Half-life (hours)	Bioavailability	
	i.v.	i.m.	s.c.
Rats			
1	42.4 ± 4.3	28.9%	14.5%
2	24.1 ± 5.0	28.9%	14.5%
4	32.1 ± 2.4	26.1%	14.9%
Rabbits			
1	88.5 ± 8.9	98.3%	84.4%
2	45.7 ± 40.6	100%	100%
4	141.1 ± 15.4	85%	83%
Dogs			
1	70.0 ± 11.7	69.5%	50.4%
Pigs			
1	178 ± 24	71.6%	76.8%

10 **[0159]** Absorption, distribution, metabolism, and excretion (*ADME*) studies were done after iodination of 9x10kD PEG-Pig-KS-ΔN uricase by the Bolton & Hunter method with ¹²⁵I. The labeled conjugate was injected into 7 groups of 4 rats each (2 males and 2 females). Distribution of radioactivity was analyzed after 1 hour and every 24 hours for 7 days (except day 5). Each

15 group, in its turn, was sacrificed and the different organs were excised and analyzed. The seventh group was kept in a metabolic cage, from which the urine and feces were collected. The distribution of the material throughout the animal's body was evaluated by measuring the total

radioactivity in each organ, and the fraction of counts (kidney, liver, lung, and spleen) that were available for precipitation with TCA (i.e. protein bound, normalized to the organ size). Of the organs that were excised, none had a higher specific radioactivity than the others, thus no significant accumulation was seen for instance in the liver or kidney. 70% of the radioactivity was excreted by day 7.

Example 8. Clinical Trial Results

[0160] A randomized, open-label, multicenter, parallel group study was performed to assess the urate response, and pharmacokinetic and safety profiles of PEG-uricase (Puricase®, Savient Pharmaceuticals) in human patients with hyperuricemia and severe gout who were unresponsive to or intolerant of conventional therapy. The mean duration of disease was 14 years and 70 percent of the study population had one or more tophi.

[0161] In the study, 41 patients (mean age of 58.1 years) were randomized to 12 weeks of treatment with intravenous PEG-uricase at one of four dose regimens: 4 mg every two weeks (7 patients); 8 mg every two weeks (8 patients); 8 mg every four weeks (13 patients); or 12 mg every four weeks (13 patients). Plasma uricase activity and urate levels were measured at defined intervals. Pharmacokinetic parameters, mean plasma urate concentration and the percentage of time that plasma urate was less than or equal to 6 mg/dL were derived from analyses of the uricase activities and urate levels.

[0162] Patients who received 8 mg of PEG-uricase every two weeks had the greatest reduction in PUA with levels below 6 mg/dL 92 percent of the treatment time (pre-treatment plasma urate of 9.1 mg/dL vs. mean plasma urate of 1.4 mg/dL over 12 weeks).

[0163] Substantial and sustained lower plasma urate levels were also observed in the other PEG-uricase treatment dosing groups: PUA below 6 mg/ml 86 percent of the treatment time in the 8 mg every four weeks group (pre-treatment plasma urate of 9.1 mg/dL vs. mean plasma urate of 2.6mg/dL over 12 weeks); PUA below 6 mg/ml 84 percent of the treatment time in the

12 mg every four weeks group (pre-treatment plasma urate of 8.5 mg/dL vs. mean plasma urate of 2.6 mg/dL over 12 weeks); and PUA below 6 mg/ml 73 percent of the treatment time in the 4 mg every two weeks group (pre-treatment plasma urate of 7.6 mg/dL vs. mean plasma urate of 4.2 mg/dL over 12 weeks).

5 **[0164]** The maximum percent decrease in plasma uric acid from baseline within the first 24 hours of PEG-uricase dosing was 72% for subjects receiving 4 mg / 2 weeks (p equals .0002); 94% for subjects receiving 8 mg / 2 weeks (p less than .0001); 87% for subjects receiving 8 mg / 4 weeks (p less than .0001); and 93% for subjects receiving 12 mg / 4 weeks (p less than .0001).

10 **[0165]** The percent decrease in plasma uric acid from baseline over the 12-week treatment period was 38% for subjects receiving 4 mg / 2 weeks (p equals .0002); 86% for subjects receiving 8 mg / 2 weeks (p less than .0001); 58% for subjects receiving 8 mg / 4 weeks (p equals .0003); and 67% for subjects receiving 12 mg / 4 weeks (p less than .0001).

[0166] Surprisingly, some subjects receiving PEG-uricase experienced an infusion related adverse event, i.e., an infusion reaction. These reactions occurred in 14% of the total infusions.

15 **[0100]** All references cited herein are incorporated herein by reference in their entirety and for all purposes to the same extent as if each individual publication or patent or patent application was specifically and individually indicated to be incorporated by reference in its entirety for all purposes.

20 **[0101]** Many modifications and variations of the present invention can be made without departing from its spirit and scope, as will be apparent to those skilled in the art. The specific embodiments described herein are offered by way of example only, and the invention is to be limited only by the terms of the appended claims along with the full scope of equivalents to which such claims are entitled.

CLAIMS

1. A pharmaceutical composition comprising:
 - (a) an isolated uricase comprising position 8 through position 287 of SEQ ID NO. 7; and
 - (b) a pharmaceutically acceptable carrier;wherein the uricase is conjugated with a polymer.
2. The pharmaceutical composition of claim 1, wherein the isolated uricase comprising the amino acid sequence of SEQ ID NO. 8.
3. The pharmaceutical composition of claim 1, wherein the isolated uricase further comprising an amino terminal amino acid, wherein the amino terminal amino acid is alanine, glycine, proline, serine, or threonine.
4. The pharmaceutical composition of claim 1, wherein the isolated uricase further comprising an amino terminal amino acid, wherein the amino terminal amino acid is methionine.
5. A pharmaceutical composition comprising:
 - (a) an isolated uricase comprising position 8 through position 287 of SEQ ID NO. 12; and
 - (b) a pharmaceutically acceptable carrier;wherein the uricase is conjugated with a polymer.
6. The pharmaceutical composition of claim 5, wherein the isolated uricase comprising the amino acid sequence of SEQ ID NO. 13.
7. The pharmaceutical composition of claim 5, wherein the isolated uricase further comprising an amino terminal amino acid, wherein the amino terminal amino acid is alanine, glycine, proline, serine, or threonine.

8. The pharmaceutical composition of claim 5, wherein the isolated uricase further comprising an amino terminal amino acid, wherein the amino terminal amino acid is methionine.
9. The pharmaceutical composition of any one of claims 1-8, wherein the polymer is selected from the group consisting of poly(ethylene glycol), dextran, polypropylene glycol, hydroxypropylmethyl cellulose, carboxymethylcellulose, polyvinyl pyrrolidone and polyvinyl alcohol.
10. The pharmaceutical composition of claim 9 comprising 2-12 polyethylene glycol molecules on each uricase subunit.
11. The pharmaceutical composition of claim 9 comprising 3-10 polyethylene glycol molecules on each uricase subunit.
12. The pharmaceutical composition of claim 9, wherein each polyethylene glycol molecule has a molecular weight of about 1 kD and 100 kD.
13. The pharmaceutical composition of claim 9, wherein each polyethylene glycol molecule has a molecular weight of about 1 kD and 50 kD.
14. The pharmaceutical composition of claim 9, wherein each polyethylene glycol molecule has a molecular weight of about 5 kD and 20 kD.
15. The pharmaceutical composition of claim 9, wherein each polyethylene glycol molecule has a molecular weight of about 10 kD.
16. The pharmaceutical composition of any one of claims 9-15, suitable for long-term administration.
17. The pharmaceutical composition of any one of claims 9-15 for use in reducing uric acid levels in a biological fluid of a subject.

18. The pharmaceutical composition for use in reducing uric acid levels in a biological fluid of a subject according to claim 17, wherein the biological fluid is blood.
19. A method for preparing a pharmaceutical composition of any one of claims 1-18, comprising: (a) preparing a conjugate of the uricase with the polymer; and (b) adding the uricase conjugate to a pharmaceutically acceptable carrier.