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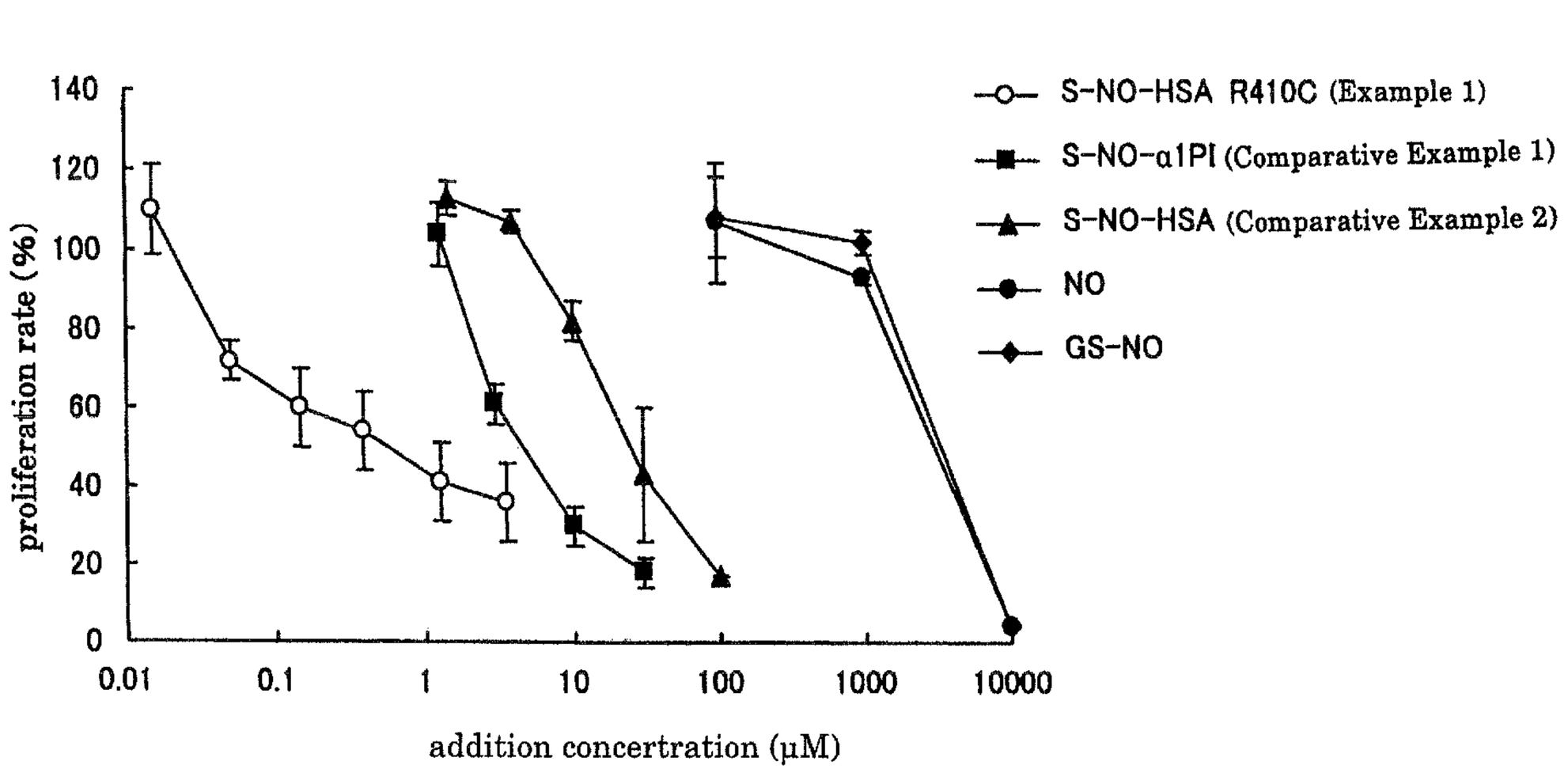
(54) Titre : ALBUMINE POSSEDANT UNE ACTIVITE ANTIMICROBIENNE ACCRUE
(54) Title: ALBUMIN HAVING ENHANCED ANTIMICROBIAL ACTIVITY



(57) Abrégé/Abstract:
The present invention provides a nitrosylated albumin variant wherein one or more amino acid residues of constituent amino acid sequences are substituted, or a different amino acid residue is inserted into a part of the constituent amino acid sequences. The albumin variant has sufficient antimicrobial property and permits application as various useful pharmaceutical compositions.

ABSTRACT OF THE DISCLOSURE

The present invention provides a nitrosylated albumin variant wherein one or more amino acid residues of constituent amino acid sequences are substituted, or a different amino acid residue is inserted into a part of the constituent amino acid sequences. The albumin variant has sufficient antimicrobial property and permits application as various useful pharmaceutical compositions.

SPECIFICATION

ALBUMIN HAVING ENHANCED ANTIMICROBIAL ACTIVITY

FIELD OF THE INVENTION

The present invention relates to a nitrosylated albumin having an antimicrobial activity. More particularly, the present invention relates to an albumin having an enhanced antimicrobial activity, which is obtained by nitrosylating an albumin variant having a biological activity similar to that of natural albumin.

BACKGROUND OF THE INVENTION

Nitric oxide (NO) is a gaseous inorganic radical, which freely diffuses in plasma membrane in a living organism, and functions as an intracellular or intercellular signaling factor.

To the present, the biological action of NO has been widely studied from various aspects, and elucidated to cover a broad range of control of vascular function, function as a neurotransmitter, biological defense systems such as inflammatory response and immunological response and the like, and the like. On the other hand, for the disease state of infection or inflammation, NO becomes a major cause of cell and/or tissue damage via oxidation and nitration reaction of biological molecules of protein, nucleic acid and the like due to active nitric-oxide species derived from NO.

Recently, various NO donors have been developed and used as clinical pharmaceutical agents based on various such physiological activities of NO. In fact, S-nitroso glutathione (hereinafter GS-NO), which is a small nitrosothiol, is known to inhibit platelet aggregation but not decrease blood pressure, and applied as a platelet aggregation inhibitor for percutaneous transluminal coronary angioplasty (PTCA) and for the treatment of preeclampsia of pregnant women.

In addition, the active nitric-oxide species derived from NO is also known to have antimicrobial property, and, for example, GS-NO is known to have an antimicrobial activity. However, the antimicrobial activity of small nitrosothiols such as GS-NO is observed only at a high concentration of a few millimolars, and they are associated with insufficient aspects and many problems as a NO donor, such as short blood half life and an adverse influence exerted by a by-product generated simultaneously with NO release.

Incidentally, there are many reports on nitrosylated polymers as well, and, for example, Stamler J.S. et al (WO96/30006, WO97/10265) have reported on the usefulness of nitrosylated proteins such as nitrosylated hemoglobin. However, inconsistent introduction rate of nitroso group into the protein can be easily anticipated because the proteins they used have plural cysteine residues. Moreover, the problems are feared that hemoglobin itself may act on vascular endothelial cells adversely, may lower renal function by deposition of iron component in the kidney tissue, and the like.

As other nitrosylated proteins, a nitrosylated form (hereinafter S-NO-α1-PI) of α1-protease inhibitor (hereinafter α1-PI) known as a major serine protease inhibitory protein in human serum has been reported (JP-A-11-147838, Y. Miyamoto, T. Akaike, H. Maeda, Biochimica Biophysica Acta, 1477, p.90-97, (2000)). It has been reported that this S-NO-α1-PI shows an antimicrobial effect at a few micromolars and shows about 1000 times stronger antimicrobial activity as compared to that of GS-NO and the like.

Meanwhile, human serum albumin (HSA) is a major protein present in adult sera, which is produced by the liver and which functions as a carrier transporting

various serum molecules. In addition, albumin plays an important role in maintaining the plasma oncotic pressure normally created by a solute (colloid) incapable of passing through capillary pores, thus maintaining the liquid content of blood. Thus, albumin is used for various treatments of conditions involving loss of liquid from blood vessels, such as surgical operation, shock, burn, hypoproteinemia causing edema and the like.

Stamler et al found nitrosylated albumin present in human plasma at the order of μM, and reported that hemoglobin cysteine residue in blood was nitrosylated. From these findings, nitrosylation of protein in living organisms is considered to be related to transportation and storage of NO and control physiological activity of NO (Stamler J.S. et al., Proc Natl Acad Sci USA, 89, p.7674-7677,(1992), Lia J et al., Nature, 380, p.221-226, (1996)).

Therefore, a nitrosylated form of albumin, which is present in the largest amount of the serum proteins and which plays a key role in living organisms is highly useful, and supply of stable nitrosylated albumin in clinical situations is significantly important. However, the reactivity of SH group of albumin is markedly lower than that of α1-PI and the like, and artificial and efficient nitrosylation of albumin has not been available.

SUMMARY OF THE INVENTION

There is a demand on the provision of albumin having sufficient antimicrobial property and permitting application as various useful pharmaceutical compositions, which is achieved by efficiently nitrosylating albumin.

In an attempt to solve the above-mentioned problems, the present inventors have analyzed efficiency of nitrosylation and antimicrobial activity thereof in various bacterial infection model animals, using an

albumin variant having a mutation in one or more amino acid residues of constituent amino acid sequences, and, as a result, found that the albumin variant is efficiently nitrosylated, and its nitrosylated form shows a stronger antimicrobial activity than do NO and small nitrosothiols, and completed the present invention.

According to one aspect of the present invention, there is provided an isolated or purified nitrosylated albumin variant of an amino acid sequence of human serum albumin, wherein the arginine residue at position 410 of the amino acid sequence of human serum albumin set forth in SEQ ID NO: 1 is substituted by a cysteine residue and wherein an average number of nitric oxide (NO) molecules per molecule of the nitrosylated albumin variant is more than 0.3 and not more than 2.

According to another aspect of the present invention, there is provided a use of a nitrosylated albumin variant of an amino acid sequence of human serum albumin for treating bacterial infection, platelet aggregation, vascular circulatory failure, or ischemia/reperfusion injury in a subject, wherein the arginine residue at position 410 of the amino acid sequence of human serum albumin set forth in SEQ ID NO: 1 is substituted by a cysteine residue and wherein an average number of nitric oxide (NO) molecules per molecule of the nitrosylated albumin variant is more than 0.3 and not more than 2.

According to still another aspect of the present invention, there is provided a use of a nitrosylated albumin variant of an amino acid sequence of human serum albumin in the manufacture of a medicament for treating bacterial infection, platelet aggregation, vascular circulatory failure, or ischemia/reperfusion injury in a subject, wherein the arginine residue at position 410 of the amino acid sequence of human serum albumin set forth in SEQ ID NO: 1 is substituted by a cysteine residue and wherein an average number of nitric oxide (NO) molecules per molecule of the nitrosylated albumin variant is more than 0.3 and not more than 2.

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That is, the present invention relates to

(1) a nitrosylated albumin variant wherein one or more amino acid residues of constituent amino acid sequences are substituted, or a different amino acid residue is inserted into a part of the constituent amino acid sequences,

(2) the variant of the above-mentioned (1), wherein one or more amino acid residues of the constituent amino acid sequences are substituted by a sulfur-containing amino acid residue,

(3) the variant of the above-mentioned (1), wherein an arginine residue of the constituent amino acid sequences is substituted by a sulfur-containing amino acid residue,

(4) the variant of the above-mentioned (1), wherein an about 410th arginine residue of the constituent amino acid sequences is substituted by a cysteine residue,

(5) the variant of the above-mentioned (1), wherein the number of the substituted or inserted amino acid residue is about 1 to 10,

(6) the variant of the above-mentioned (1), wherein the albumin variant is a variant of human serum albumin,

(7) the variant of the above-mentioned (1), wherein the albumin variant is produced by gene recombination technique,

(8) the variant of the above-mentioned (1), wherein the albumin variant has a physiological activity similar to that of natural albumin,

(9) a nitrosylated albumin variant having an antimicrobial

activity,

(10) a pharmaceutical agent comprising a variant of any of the above-mentioned (1) to (9), and

(11) a nitric oxide donor comprising a variant of any of the above-mentioned (1) to (9).

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 explains a method of quantifying NO addition rate for an S-nitrosylated protein by HPLC.

Figure 2 shows a residual rate of a nitroso group of an S-nitrosylated protein before and after freeze drying.

Figure 3 shows antimicrobial activity of various S-nitrosylated proteins.

DETAILED DESCRIPTION OF THE INVENTION

The nitrosylated albumin variant of the present invention shows an antimicrobial activity at a lower concentration than do conventional antimicrobial agents. Therefore, an antimicrobial activity effective in living organism can be exhibited by only administering a pharmaceutical composition containing a small amount of a nitrosylated albumin variant.

The nitrosylated albumin variant of the present invention can be also used as one component of a pharmaceutical product as an NO (nitroso) donor.

Moreover, the nitrosylated albumin variant of the present invention can be preserved by freeze drying because the nitroso group can be stably present after freeze drying.

Moreover, the nitrosylated albumin variant of the present invention can be used safely without fear of infection with virus and the like by producing an albumin variant to be nitrosylated with gene recombinantion techniques.

In the present invention, nitrosylation means addition of a nitroso group (-NO). Nitrosylation of an

albumin variant is preferably achieved by adding a nitroso group to a thiol group of the albumin variant and performed by a known method such as reaction with nitrite. While nitrosylation of proteins such as hemoglobin was successfully done in some cases, in general, nitrosylation of protein requires reactions under severe conditions. Thus, a method capable of introducing No into a thiol group under milder conditions is preferably employed, and a method using isoamylnitrite (De Master E.G. et al., Biochemistry, 34, p. 11494-11499, 1995) and a method comprising reaction with n-butylnitrite (Meyer D.J. et al., FEBS Letters, 345, p. 177-180, 1994) can be preferably used.

In the albumin variant of the present invention, one or more amino acid residues of the constituent amino acid sequences are substituted or inserted. A preferable albumin variant is one wherein one or more amino acid residues of the constituent amino acid sequences are converted to sulfur-containing amino acid residues. As the sulfur-containing amino acid residue, cysteine residue, cystine residue and methionine residue can be mentioned, with particular preference given to cysteine residue. In addition, an albumin variant wherein an arginine residue of the constituent amino acid sequences is substituted by a sulfur-containing amino acid residue is preferable, and an albumin variant wherein about 410th arginine residue of the constituent amino acid sequences is substituted by a sulfur-containing amino acid residue is preferable. As the albumin variant of the present invention, an albumin variant wherein about 410th arginine residue of the constituent amino acid sequences is mutated to a cysteine residue (hereinafter HSA-R410C) can be preferably used.

In the albumin variant of the present invention, the number of the substituted or inserted amino acid residues

is preferably about 1 to 10, more preferably about 1 to 5.

While the complete protein sequences of HSA have been already reported publicly (JP-A-8-228790 etc.), the protein sequences of HSA so far reported contain about 20 inconsistent residues, and the total number of amino acids of mature protein reported heretofore also varies. HSA-R410C, which is the above-mentioned albumin variant, is also naturally present in a small amount as one kind thereof. In the present invention, such an albumin naturally present in a small amount is also included in the albumin variants, as long as it is other than the albumin naturally present in the highest amount, which is referred to as natural albumin in the present invention. Moreover, the amino acid residue mutation site (Arg→Cys) of HSA-R410C used as one example in the present invention may be one or more positions different from the 410th position when the total number of amino acids differs.

The albumin variant of the present invention is preferably a variant of human serum albumin, and preferably a gene recombinant albumin. Serum albumin produced by fractionation of whole blood cannot be obtained in a large amount at a reasonable cost. However, when a gene recombination technique is adapted and a microorganism genetically engineered to efficiently produce albumin is used, the above-mentioned albumin variant and the like can be produced abundantly. The complete protein sequences of HSA have been already made public (JP-A-8-228790 etc.), and the albumin variant of the present invention can be produced by a method utilizing various known gene recombination techniques.

In addition, the albumin variant of the present invention preferably has the same physiological activity as does natural albumin. By the same physiological activity as does natural albumin is meant one having

substantially the same function as natural albumin, such as not causing a rejection reaction in a living organism, maintaining normal osmolarity in blood flow, and function as a carrier to transport various serum molecules and the like.

An S-nitrosylated form of α1-PIox (hereinafter S-NO-α1-PIox), which is obtained by further S-nitrosylation of α1-PI (hereinafter α1-PIox) wherein methionine (Met), which is an active center of α1-PI, was chemically oxidized, was studied for its growth inhibitory activity on Salmonella typhimurium in vitro. As a result, it was reported that its antimicrobial activity was about 100 times stronger than that of S-NO-α1-PI and the S-nitrosylated form was capable of inhibiting growth of bacteria at a few dozen nanomolars (JP-A-11-147383, Y. Miyamoto, T. Akaike, H. Maeda, Biochimica Biophysica Acta, 1477, p.90-97, (2000)). This suggests the possibility that, when S-NO-α1-PI produced at the site of infection is oxidized (oxidization of Met) by active oxygen species produced simultaneously with NO, the antimicrobial activity of an active form thereof may be further enhanced, and in the present invention, too, the antimicrobial activity is considered to be further enhanced by oxidization of methionine (Met) residue etc. of the albumin variant in the preliminary step toward nitrosylation.

A nitric oxide donor containing the albumin variant of the present invention can be used as an antimicrobial agent, a vascular circulatory failure improving agent, an antiplatelet agent, an ischemia/reperfusion injury suppressant and the like, which contain the variant as a major ingredient.

The present invention is explained in detail by referring to Examples and Reference Examples, which are

not to be construed as limitative.

Example 1

A recombinant protein of a human serum albumin variant (hereinafter HSA-R410C), wherein the 410th arginine (Arg) in the amino acid sequence of a human serum albumin (hereinafter HSA) has been mutated into cysteine (Cys), was prepared, 1,4-dithiothreitol (hereinafter DTT) was added in amount of 10 times the molar amount of the variant, and the mixture was reacted at 37°C for 5 min to reduce SH group of free Cys residue in HSA. To confirm reduction of SH group of HSA by a DTT treatment, HSA and impurities such as DTT and the like were separated, after which SH group was quantified using the 5,5'-dithiobis-2-nitrobenzoic acid (DTNB) method, whereby the SH group of all free Cys residues was confirmed to have been reduced. Then, 0.1 M isoamyl nitrate was added in an amount 100 times the amount of DTT treated HSA. The mixture was reacted at 37°C for 1 hr to allow nitrosylation to give nitrosylated HSA (S-NO-HSA).

Comparative Example 1

A reaction similar to that in Example 1 was performed using a natural HSA (hereinafter nHSA) to give nitrosylated HSA (S-NO-nHSA).

Comparative Example 2

A reaction similar to that in Example 1 was performed using an α1-protease inhibitor (α1-PI) to give nitrosylated α1-PI (S-NO-α1-PI).

Experimental Example 1: quantification of NO addition rate of S-nitrosylated protein by HPLC

An NO addition rate of nitrosylated protein was quantified according to the method of Akaike et al (T. Akaike, et al., J. Biochemistry, 122, 459-466, 1997). To be specific, various S-nitrosylated proteins obtained in Example 1, Comparative Example 2 and Comparative Example

3, which were separated by HPLC shown in Fig. 1. Thereto was added Hg^{2+} to give NO^{2-} in the elution circuit, further mixed with a Griess reagent, and the flow reactor was constructed. An azo dye produced by the reaction of NO^{2-} with the Griess reagent was measured at 540 nm, whereby various S-nitrosylated proteins were separated and quantified.

The results of measurement of NO addition rate of S-NO-protein by HPLC are shown in Table 1.

The NO introduction efficiency of Comparative Example 2 (S-NO-a1-PI) was about 1.0 (mol/molecule), whereas it was extremely low and about 0.3 (mol/molecule) in Comparative Example 1 (S-NO-nHSA).

In contrast, NO introduction efficiency of Example 1 (S-NO-HSA-R410C) was highly efficient and was about 1.30 (mol/molecule), whereby efficient nitrosylation was confirmed.

Table 1: NO addition rate of various S-nitrosylated proteins

	number of SH group per molecule	NO addition rate (mol/molecule)
Example 1: HSA (R410)	2	1.29±0.09
Comparative Example 1: nHSA	1	0.29±0.03
Comparative Example 2: α_1PI	1	1.00±0.07

Experimental Example 2

The nitroso group residual ratio of S-nitrosylated protein before and after freeze drying was measured.

Various S-nitrosylated proteins obtained in Example 1, Comparative Example 2 and Comparative Example 3 were dissolved in phosphate buffer (pH 7.4) containing 1 mM diethilenetriamine pentaacetic acid (DTPA), the residual amount of nitroso group was measured by HPLC, wherein its

peak area was taken as 100% as a nitroso group residual amount at 0 hr, and the nitroso group was quantitatively determined to evaluate the residual amount. At the same time, the amount of the nitroso group before and after freeze drying was measured by HPLC, wherein the peak area before freeze drying was taken as 100%, and the residual amount of nitroso group was evaluated. The results are shown in Figure 2.

As a result, various S-nitroso compounds obtained in Example 1, Comparative Example 1 and Comparative Example 2 all showed a high nitroso group residual ratio of not less than 80% after freeze drying relative to that before freeze drying.

While not shown in the data, the stability of S-NO-protein in the solution was examined and all S-NO-proteins were confirmed to be highly stable as evidenced by a half life of about 20 days.

Experimental Example 3

Using Salmonella typhimurium LT2 strain, the activities of various S-nitroso compounds were compared.

The Salmonella typhimurium LT2 strain was cultured overnight in an M9 medium containing 20 wt% glucose (Na_2HPO_4 64 g, KH_2PO_4 15 g, NaCl 2.5 g, NH_4Cl 5 g/1 L), washed 3 times with M9 and the number of bacteria was adjusted to 2×10^6 cfu/mL in an M9 medium. To this medium were added various S-nitrosylated proteins obtained in Example 1, Comparative Example 1 and Comparative Example 2, nitric oxide (NO) or S-nitroso glutathione (GS-NO) as Comparative Example, and the mixture was reacted at 37°C for 9 hr, after which the absorbance at wavelength 655 nm was measured and the ratio based on the absorbance of the control group without addition as 100% was calculated as a growth rate (%).

The results are shown in Figure 3. In Example 1, a

strong antimicrobial activity was observed as compared to NO and small GS-NO, and also a superior antimicrobial activity was observed as compared to Comparative Example 1 and Comparative Example 2.

Therefore, the S-nitrosylated serum protein of the present invention has been shown to have a stronger antimicrobial activity as compared to NO, small GS-NO and the like.

The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the appended claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e. g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specification should be construed as indicating any non- claimed element as essential to the practice of the invention.

Preferred embodiments of this invention are

described herein, including the best mode known to the inventors for carrying out the invention. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifications and equivalents of the subject matter within the scope of the claims appended hereto as permitted by applicable law. Moreover, any combination of the above-described elements in all possible variations thereof is encompassed by the invention as claimed unless otherwise indicated herein or otherwise clearly contradicted by context.

This application is based on application No. 2003-433387 filed in Japan.

SEQUENCE LISTING IN ELECTRONIC FORM

In accordance with Section 111(1) of the Patent Rules, this description contains a sequence listing in electronic form in ASCII text format (file: 27103-443 Seq 27-OCT-09 v1.txt).

A copy of the sequence listing in electronic form is available from the Canadian Intellectual Property Office.

The sequences in the sequence listing in electronic form are reproduced in the following table.

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CLAIMS:

1. An isolated or purified nitrosylated albumin variant of an amino acid sequence of human serum albumin, wherein the arginine residue at position 410 of the amino acid sequence of human serum albumin set forth in SEQ ID NO: 1 is substituted by a cysteine residue and wherein an average number of nitric oxide (NO) molecules per molecule of the nitrosylated albumin variant is more than 0.3 and not more than 2.

2. The variant of claim 1, wherein the albumin variant to be nitrosylated is produced by gene recombination technique.

3. The variant of claim 1 or 2, wherein the albumin variant has at least one of the following physiological activities (a) to (c) similar to those of natural albumin:

(a) not causing a rejection reaction in a living organism,

(b) maintaining normal osmolarity in blood, and

(c) functioning as a carrier to transport serum molecules.

4. The variant of any one of claims 1 to 3, wherein the albumin variant has an antimicrobial activity.

5. The variant of any one of claims 1 to 4, wherein the average number of NO molecules per molecule of the nitrosylated albumin variant is more than 1.3.

6. The variant of any one of claims 1 to 4, wherein the average number of NO molecules per molecule of the nitrosylated albumin variant is 1.3.

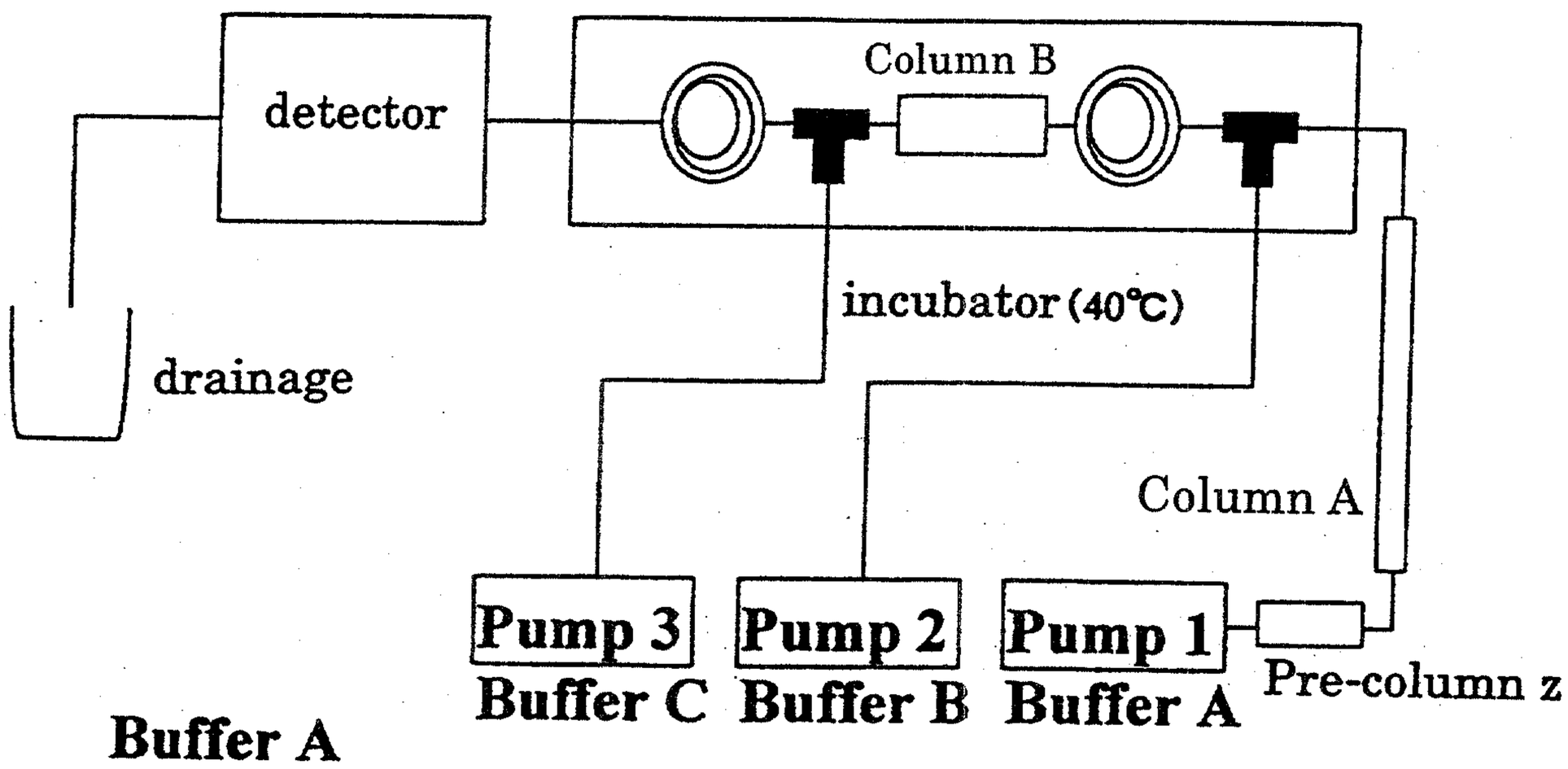
7. The variant of any one of claims 1 to 4, wherein the average number of NO molecules per molecule of the nitrosylated albumin variant is not more than 1.3.

8. A composition comprising the variant of any one of claims 1 to 7, and a pharmaceutically acceptable carrier.

9. A use of a nitrosylated albumin variant of an amino acid sequence of human serum albumin for treating bacterial infection, platelet aggregation, vascular circulatory failure, or ischemia/reperfusion injury in a subject, wherein the arginine residue at position 410 of the amino acid sequence of human serum albumin set forth in SEQ ID NO: 1 is substituted by a cysteine residue and wherein an average number of nitric oxide (NO) molecules per molecule of the nitrosylated albumin variant is more than 0.3 and not more than 2.

10. A use of a nitrosylated albumin variant of an amino acid sequence of human serum albumin in the manufacture of a medicament for treating bacterial infection, platelet aggregation, vascular circulatory failure, or ischemia/reperfusion injury in a subject, wherein the arginine residue at position 410 of the amino acid sequence of human serum albumin set forth in SEQ ID NO: 1 is substituted by a cysteine residue and wherein an average number of nitric oxide (NO) molecules per molecule of the nitrosylated albumin variant is more than 0.3 and not more than 2.

FIG. 1



Buffer A

0.1 M NaCl + 0.5 mM DTPA + 10 mM AcONa (pH 5.5)

Buffer B

3 mM $HgCl_2$ + 10 mM AcONa (pH 5.5)

Buffer C

Griess reagent

Column A : gel filtration column

Column B : deproteinization column

FIG. 2

Residual rate of nitroso group of S-nitrosylated protein before and after freeze drying

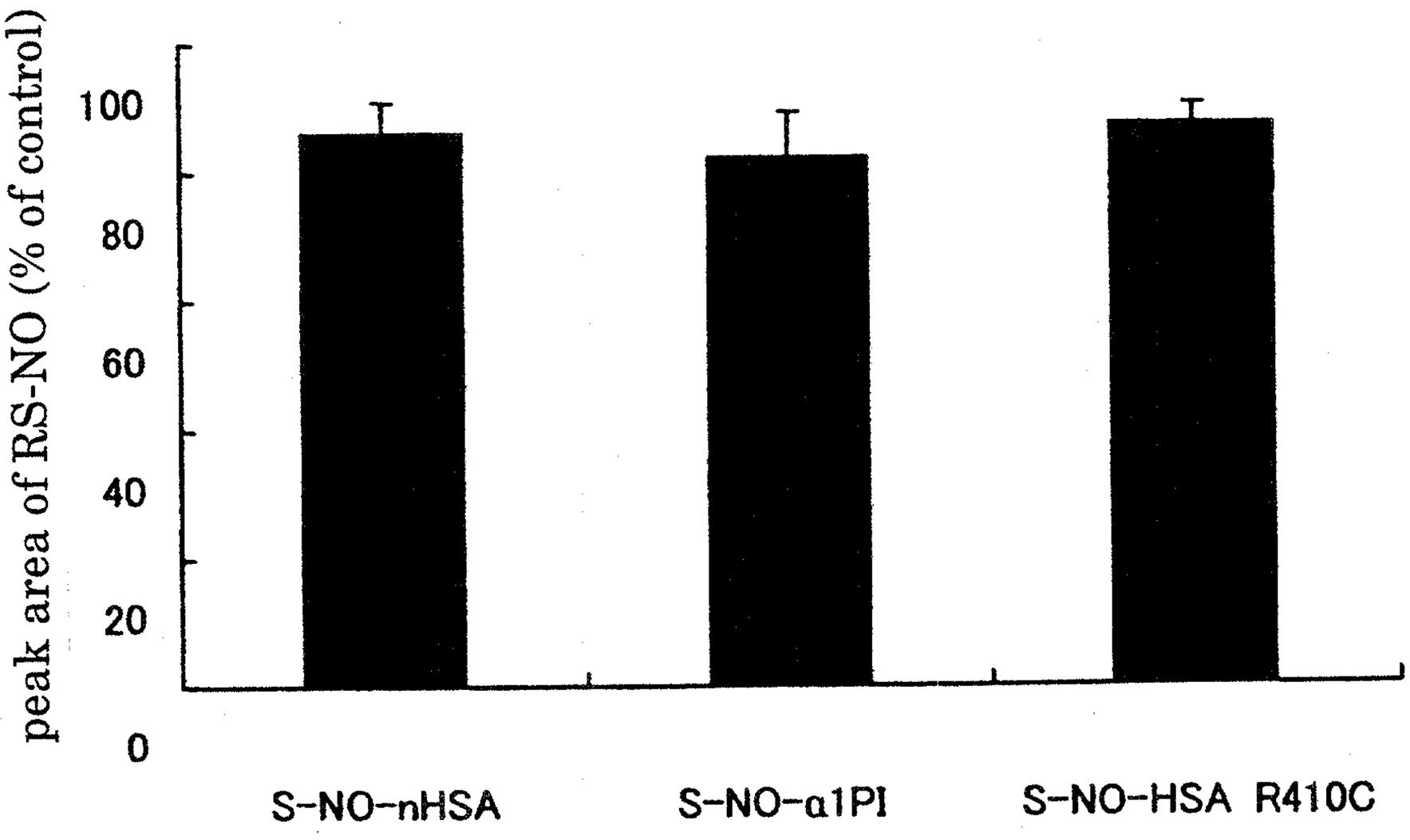
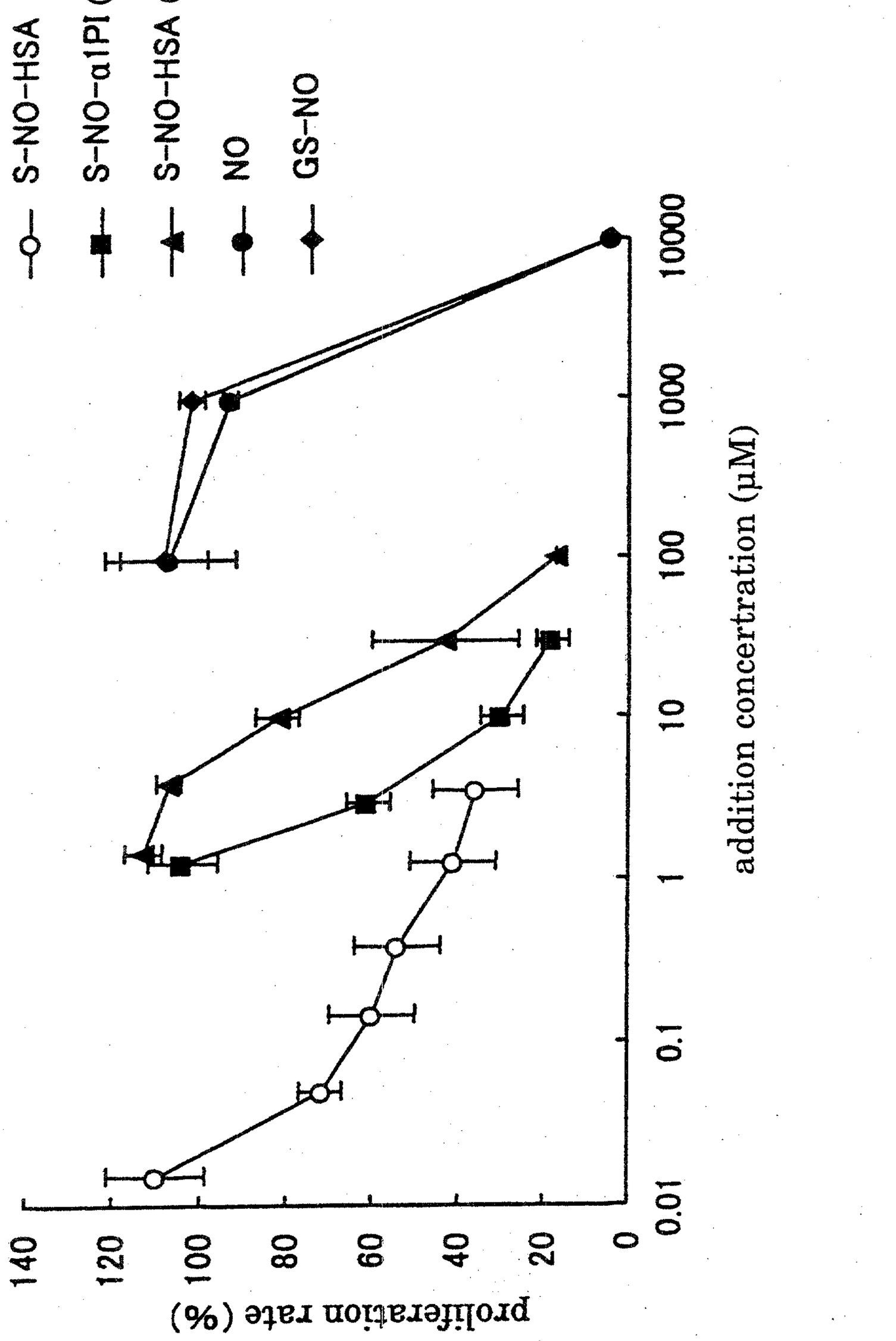


FIG. 3

Comparison of antimicrobial activities of various S-nitrosylated proteins in Salmonera. typhimuriumLT2



Comparison of antimicrobial activities of various S-nitrosylated proteins in Salmonera. typhimuriumLT2