

DESCRIPTION

AN AGENT FOR MEASURING ENDOTOXIN

TECHNICAL FIELD

[0001]

The present invention relates to an endotoxin-measuring agent, a method for producing the measuring agent, and a method for measuring endotoxin in a sample.

BACKGROUND ART

[0002]

Endotoxin is a lipopolysaccharide existing on the outer membrane of the cell wall of Gram-negative bacteria, and known to be a strong pyrogen. Further, it is known that even a small amount of endotoxin causes various disease states due to bacterial infection, such as release of inflammatory cytokines due to macrophage activation and induction of endotoxin shock, in addition to fever. Therefore, detection of endotoxin in pharmaceuticals such as those for injection; water; medical equipments; and the like is important. Further, endotoxin is considered to be the main cause of shock in Gram-negative bacterial infection, and hence, the presence or absence of infection and/or a pharmaceutical effect can be judged by measuring endotoxin in the blood.

[0003]

Further, it is known that infection of American horseshoe crab (*Limulus polyphemus*) with Gram-negative

bacteria causes intravascular coagulation, and this phenomenon has been used for detection of endotoxin.

[0004]

That is, a method for measuring endotoxin using a blood cell extract of a horseshoe crab (horseshoe crab amebocyte lysate; hereinafter also referred to as "lysate") is known (e.g., Non-patent Document 1). This method is called "limulus test", and uses a cascade reaction of various proteins existing in the lysate, which reaction is caused by contacting of endotoxin with the lysate. A schematic diagram of the cascade reaction is shown in Fig. 1.

[0005]

Upon contacting of endotoxin with the lysate, factor C existing in the lysate is activated to produce active-type factor C. This active-type factor C activates factor B existing in the lysate, to produce active-type factor B. This active-type factor B then activates a proclotting enzyme existing in the lysate, to produce a clotting enzyme.

[0006]

This clotting enzyme hydrolyzes a specific portion in the coagulogen molecule existing in the lysate. By this, coagulin gel is produced, to cause coagulation of the lysate. Thus, by measuring the coagulation reaction of the lysate, endotoxin can be measured.

[0007]

Further, also by allowing a clotting enzyme to react

with a synthetic substrate to cause color reaction, endotoxin can be measured. For example, a clotting enzyme reacts with a synthetic substrate t-butoxycarbonyl-leucyl-glycyl-arginyl-pNA (Boc-Leu-Gly-Arg-pNA) to hydrolyze its amide bond, and thereby pNA is released. Thus, by preliminarily including the synthetic substrate in the reaction system, endotoxin can be quantified by measurement of the absorbance (405 nm) of the coloring substance (pNA).

[0008]

Further, it is known that the cascade reaction system can be reconstructed using factor C, factor B, and a proclotting enzyme, which were purified from lysate of a Japanese horseshoe crab (Non-patent Document 2).

[0009]

Further, a case wherein a recombinant factor C derived from a Southeast Asian horseshoe crab *Carcinoscorpius rotundicauda*; and a recombinant factor B and a recombinant proclotting enzyme derived from a Japanese horseshoe crab *Tachypleus tridentatus*; were used to reconstruct the cascade reaction system is known (Patent Document 1).

[0010]

Further, a system for detecting endotoxin by using a recombinant factor C derived from a Southeast Asian horseshoe crab *Carcinoscorpius rotundicauda* and a substrate that reacts with active-type factor C to release a fluorescent substance is known (Patent Document

2). This system is commercially available as an endotoxin detection system (commercial name: PyroGene (registered trademark); Lonza).

[0011]

However, in order to use the lysate, or the naturally occurring factor C, factor B, and proclotting enzyme prepared therefrom, it is necessary to capture horseshoe crabs and collect blood therefrom. Hence, in view of conservation of biological resources or the like, it is difficult to supply these components unlimitedly. Therefore, a technique to easily and rapidly produce a reagent for detection of endotoxin at a low cost has been demanded.

[0012]

Further, in cases where a recombinant factor C, recombinant factor B, and recombinant proclotting enzyme are used, any of the above-described cases requires 1 hour or more for the measurement, and a detection sensitivity in the order of 0.001 EU/mL has not been achieved. Therefore, a technique to rapidly and highly sensitively measure endotoxin has been demanded.

PRIOR ART DOCUMENTS

Patent Documents

[0013]

[Patent Document 1] WO 2008/004674

[Patent Document 2] US 6,849,426 B

Non-patent Documents

[0014]

[Non-patent Document 1] Iwanaga S., Curr Opin Immunol. 1993 Feb; 5(1): 74-82.

[Non-patent Document 2] Nakamura T. et al., J Biochem. 1986 Mar; 99(3): 847-57.

SUMMARY OF THE INVENTION

[0015]

The present invention aims to provide a method for rapidly and highly sensitively measuring endotoxin. The present invention also aims to provide an endotoxin-measuring agent to be used in the method, and a method for producing the agent.

[0016]

The present inventors discovered that endotoxin can be rapidly and highly sensitively measured by using a recombinant factor C (His-tag free), recombinant factor B and recombinant proclotting enzyme, which were derived from a Japanese horseshoe crab *Tachypleus tridentatus* and expressed using insect cells as a host, thereby completing the present invention.

[0017]

That is, the present invention is as follows.

[1]

An endotoxin-measuring agent comprising the proteins (1) to (3) below, each of which is a recombinant protein obtainable by being expressed using insect cells as a host:

(1) a factor C derived from *Tachypleus tridentatus*, which factor C does not have His-tag sequence at the C-terminus;

(2) a factor B of a horseshoe crab; and

(3) a proclotting enzyme of a horseshoe crab.

[2]

The measuring agent according to [1], wherein said factor B and said proclotting enzyme are derived from *Tachypleus tridentatus*.

[3]

The measuring agent according to [1] or [2], wherein said factor C is the protein (A) or (B) below; said factor B is the protein (C) or (D) below; and said proclotting enzyme is the protein (E) or (F) below:

(A) a protein comprising the amino acid sequence shown in SEQ ID NO:2;

(B) a protein comprising the amino acid sequence shown in SEQ ID NO:2 but which includes substitution, deletion, insertion, or addition of one or several amino acid residues, which protein has factor C activity;

(C) a protein comprising the amino acid sequence shown in SEQ ID NO:4;

(D) a protein comprising the amino acid sequence shown in SEQ ID NO:4 but which includes substitution, deletion, insertion, or addition of one or several amino acid residues, which protein has factor B activity;

(E) a protein comprising the amino acid sequence shown in SEQ ID NO:6;

(F) a protein comprising the amino acid sequence shown in SEQ ID NO:6 but which includes substitution, deletion, insertion, or addition of one or several amino acid residues, which protein has proclotting enzyme activity.

[4]

A method for producing the measuring agent according to any one of [1] to [3], the method comprising the steps (A) to (C) below:

(A) a step of incorporating each of the DNAs (1) to (3) below into a viral DNA:

(1) a DNA encoding a factor C derived from *Tachyplesus tridentatus*, which factor C does not have His-tag sequence at the C-terminus;

(2) a DNA encoding a factor B of a horseshoe crab; and

(3) a DNA encoding a proclotting enzyme of a horseshoe crab;

(B) a step of infecting insect cells with the virus into which said each DNA was incorporated; and

(C) a step of allowing the insect cells infected with said each virus to express the protein encoded by said each DNA.

[5]

A method for producing the measuring agent according to any one of [1] to [3], the method comprising the steps (A) to (C) below:

(A) a step of incorporating each of the DNAs (1) to

(3) below into a vector:

(1) a DNA encoding a factor C derived from *Tachypleus tridentatus*, which factor C does not have His-tag sequence at the C-terminus;

(2) a DNA encoding a factor B of a horseshoe crab; and

(3) a DNA encoding a proclotting enzyme of a horseshoe crab;

(B) a step of introducing the vector, into which said each DNA was incorporated, into insect cells to incorporate said each DNA into the chromosome of the insect cells; and

(C) a step of allowing the insect cells, into which said each DNA was incorporated, to express the protein encoded by said each DNA.

[6]

The method according to [4] or [5], wherein said DNA encoding factor C is the DNA (A) or (B) below; said DNA encoding factor B is the DNA (C) or (D) below; and said DNA encoding proclotting enzyme is the DNA (E) or (F) below:

(A) a DNA comprising the nucleotide sequence shown in SEQ ID NO:1;

(B) a DNA which hybridizes with the complementary sequence of the full length or a part of the nucleotide sequence shown in SEQ ID NO:1 under stringent conditions, and encodes a protein having factor C activity.

(C) a DNA comprising the nucleotide sequence shown in

SEQ ID NO:3 or 8;

(D) a DNA which hybridizes with the complementary sequence of the full length or a part of the nucleotide sequence shown in SEQ ID NO:3 or 8 under stringent conditions, and encodes a protein having factor B activity.

(E) a DNA comprising the nucleotide sequence shown in SEQ ID NO:5 or 9;

(F) a DNA which hybridizes with the complementary sequence of the full length or a part of the nucleotide sequence shown in SEQ ID NO:5 or 9 under stringent conditions, and encodes a protein having proclotting enzyme activity.

[7]

A method for measuring endotoxin in a test sample, the method comprising a step of mixing the measuring agent according to any one of [1] to [3] with the test sample and a step of measuring progress of cascade reaction.

[8]

The method according to [7], which comprises a step of adding a substrate for detection of progress of cascade reaction to a reaction system.

[9]

The method according to [8], which further comprises a step of calculating the endotoxin level in the test sample on the basis of reaction of said substrate.

[0018]

By the present invention, endotoxin can be rapidly and highly sensitively measured. For example, in one embodiment of the present invention, a detection sensitivity in the order of 0.0005 EU/mL can be achieved with only 30 minutes of measurement. Further, in the present invention, the expressed recombinant factor C, recombinant factor B, and recombinant proclotting enzyme can be used without purification, and hence, an endotoxin-measuring agent comprising these recombinant proteins can be simply and rapidly produced at a low cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

[Fig. 1] Fig. 1 is a diagram showing the cascade reaction system in a limulus test.

[Fig. 2] Fig. 2 is a diagram showing the structure of the vector pIZ/V5-His and the position of insertion of each of the genes. The arrow in the upper part indicates the position of insertion of the genes.

[Fig. 3] Fig. 3 is a photograph showing the expression levels of various factor Cs.

[Fig. 4] Fig. 4 is a diagram showing the activities of various factor Cs.

[Fig. 5] Fig. 5 is a photograph showing the stability of the factor C expressed by the viral method.

[Fig. 6] Fig. 6 is a photograph showing the stability of the factor C expressed by the stably expressing cell

method.

[Fig. 7] Fig. 7 is a diagram showing the effect of treatment by hollow fiber membrane filtration on the reactivities of the factors expressed by the viral method.

[Fig. 8] Fig. 8 is a diagram showing the reactivity of the endotoxin-measuring agent containing the factors expressed by the viral method.

[Fig. 9] Fig. 9 is a diagram showing the reactivity of the endotoxin-measuring agent containing the factors expressed by the stably expressing cell line method. (a) The reactivity at the endotoxin concentration of 0 to 0.1 EU/mL. (b) The reactivity at the endotoxin concentration of 0 to 0.01 EU/mL.

[Fig. 10] Fig. 10 is a photograph showing the purities and concentrations of the purified recombinant factor C and the purified naturally-occurring factor C.

[Fig. 11] Fig. 11 is a calibration curve showing a relationship between band intensities and amounts of BSA.

[Fig. 12] Fig. 12 is a diagram showing the activities of the purified recombinant factor C and the purified naturally-occurring factor C.

MODE FOR CARRYING OUT THE INVENTION

[0020]

In the present invention, a series of reactions wherein endotoxin activates factor C to produce active-type factor C; the active-type factor C activates factor

B to produce active-type factor B; and the active-type factor B activates a proclotting enzyme to produce a clotting enzyme; may be referred to as "cascade reaction".

[0021]

(1) Endotoxin-measuring Agent of Present Invention

The endotoxin-measuring agent of the present invention comprises factor C, factor B, and a proclotting enzyme. The factor C, factor B, and proclotting enzyme comprised in the endotoxin-measuring agent of the present invention may be hereinafter referred to as "factor C of the present invention", "factor B of the present invention" and "proclotting enzyme of the present invention", respectively. Further, the factor C, factor B, and proclotting enzyme may be collectively referred to as "factors".

[0022]

All of the factor C of the present invention, factor B of the present invention, and proclotting enzyme of the present invention are recombinant proteins obtainable by being expressed using insect cells as a host.

[0023]

The factor C of the present invention is a factor C derived from a Japanese horseshoe crab *Tachypleus tridentatus*. The factor C of the present invention is characterized in that it does not have a His-tag attached at the C-terminus. Further, the factor C of the present invention preferably does not have a V5-tag at the C-

terminus. Further, the factor C of the present invention more preferably does not have any peptide attached at the C-terminus. Further, the factor C of the present invention especially preferably does not have any peptide attached at either terminus. An amino acid sequence of the factor C of *Tachypleus tridentatus* is shown in SEQ ID NO:2. A nucleotide sequence of the gene encoding the factor C of *Tachypleus tridentatus* is shown in SEQ ID NO:1.

[0024]

The factor C of the present invention may be a variant of the protein having the amino acid sequence shown in SEQ ID NO:2 as long as the variant has the factor C activity.

[0025]

The "factor C activity" means an activity by which factor C becomes active-type factor C in the presence of endotoxin, to activate factor B. The fact that the factor C of the present invention "has the factor C activity" can be confirmed, for example, by using the factor C of the present invention in combination with a suitable factor B and a suitable proclotting enzyme, and detecting the progress of the cascade reaction in the presence of endotoxin. More particularly, the protein of SEQ ID NO:4 may be used as the suitable factor B, and the protein of SEQ ID NO:6 may be used as the suitable proclotting enzyme. The progress of the cascade reaction can be measured using the later-mentioned substrate for

detection.

[0026]

The factor C of the present invention may be a protein comprising the amino acid sequence shown in SEQ ID NO:2 but which includes substitution, deletion, insertion, or addition of one or several amino acid residues as long as the factor C has the factor C activity. The meaning of the term "one or several" varies depending on the positions of the amino acid residues in the three-dimensional structure of the protein and the types of the amino acid residues, and, more particularly, the term means preferably 1 to 20, more preferably 1 to 10, still more preferably 1 to 5, especially preferably 1 to 3. The above-described substitution, deletion, insertion, or addition of one or several amino acids is a conservative mutation that maintains the normal function of the protein. A representative example of the conservative mutation is a conservative substitution. The conservative substitution is, for example, a mutation wherein substitution takes place mutually among Phe, Trp, and Tyr, if the substitution site is an aromatic amino acid; among Leu, Ile, and Val, if the substitution site is a hydrophobic amino acid; between Gln and Asn, if the substitution site is a polar amino acid; among Lys, Arg, and His, if the substitution site is a basic amino acid; between Asp and Glu, if the substitution site is an acidic amino acid; and between Ser and Thr, if it the substitution site an

amino acid having a hydroxyl group. Examples of substitutions considered as conservative substitutions include, specifically, substitution of Ser or Thr for Ala, substitution of Gln, His, or Lys for Arg, substitution of Glu, Gln, Lys, His, or Asp for Asn, substitution of Asn, Glu, or Gln for Asp, substitution of Ser or Ala for Cys, substitution of Asn, Glu, Lys, His, Asp, or Arg for Gln, substitution of Gly, Asn, Gln, Lys, or Asp for Glu, substitution of Pro for Gly, substitution of Asn, Lys, Gln, Arg, or Tyr for His, substitution of Leu, Met, Val, or Phe for Ile, substitution of Ile, Met, Val, or Phe for Leu, substitution of Asn, Glu, Gln, His, or Arg for Lys, substitution of Ile, Leu, Val, or Phe for Met, substitution of Trp, Tyr, Met, Ile, or Leu for Phe, substitution of Thr or Ala for Ser, substitution of Ser or Ala for Thr, substitution of Phe or Tyr for Trp, substitution of His, Phe, or Trp for Tyr, and substitution of Met, Ile, or Leu for Val. Further, the above-described substitution, deletion, insertion, addition, inversion or the like may also include a naturally occurring mutation due to difference in the individual, strain, or species among the horseshoe crabs from which the gene was derived.

[0027]

Further, the factor C of the present invention may be a protein which has a homology or identity of not less than 80%, preferably not less than 90%, more preferably not less than 95%, still more preferably not less than

97%, especially preferably not less than 99% to the full length of the amino acid sequence of factor C as described above, for example, to the full length of the amino acid sequence shown in SEQ ID NO:2, and has the factor C activity.

[0028]

The gene encoding the factor C of the present invention is not particularly restricted as long as the gene encodes the factor C of the present invention as described above. The gene encoding the factor C of the present invention may be a probe prepared based on a known gene sequence, for example, a DNA which hybridizes with the complementary sequence of the full length or a part of the nucleotide sequence shown in SEQ ID NO:1 under stringent conditions and encodes a protein having the factor C activity. The term "stringent conditions" herein means conditions under which the so-called specific hybrid is formed but a non-specific hybrid is not formed. Examples of the conditions include conditions under which highly homologous DNAs hybridize to each other, for example, DNAs not less than 80% homologous, preferably not less than 90% homologous, more preferably not less than 95% homologous, still more preferably not less than 97% homologous, especially preferably not less than 99% homologous, hybridize to each other, while DNAs less homologous than the above do not hybridize to each other; and conditions under which washing is carried out once, more preferably 2 or 3

times, at a salt concentration and temperature corresponding to 60°C, 1×SSC, and 0.1% SDS; preferably 60°C, 0.1×SSC, and 0.1% SDS; more preferably 68°C, 0.1×SSC, and 0.1% SDS; which are normal washing conditions in Southern hybridization.

[0029]

Further, the combinations of the codons in the gene encoding the factor C of the present invention may be modified such that the gene is optimized for being expressed in insect cell. The optimization can be carried out using, for example, a generally available contract service. The gene encoding the factor C of the present invention may be a variant of a DNA whose combinations of the codons are optimized for expression in insect cells.

[0030]

The above description on variants of the gene and protein may be applied similarly to the factor B and proclotting enzyme of the present invention, and to the genes encoding those.

[0031]

The factor B of the present invention is a factor B derived from a horseshoe crab. Further, the proclotting enzyme of the present invention is a proclotting enzyme derived from a horseshoe crab. Examples of the horseshoe crab include a Japanese horseshoe crab *Tachypleus tridentatus*, American horseshoe crab *Limulus polyphemus*, Southeast Asian horseshoe crab *Carcinoscorpius*

rotundicauda and Southeast Asian horseshoe crab *Tachypleus gigas*. The above factors are preferably derived from, among those horseshoe crabs, the Japanese horseshoe crab *Tachypleus tridentatus*.

[0032]

Amino acid sequences of the factor B and proclotting enzyme of *Tachypleus tridentatus* are shown in SEQ ID NOs:4 and 6, respectively. Nucleotide sequences of the genes encoding the factor B and proclotting enzyme of *Tachypleus tridentatus* are shown in SEQ ID NOs:3 and 5, respectively.

[0033]

The factor B of the present invention may be a variant of the factor B of any of the above-described horseshoe crabs, for example, a variant of the protein having the amino acid sequence shown in SEQ ID NO:4, as long as the factor B of the present invention has the factor B activity. Further, the gene encoding the factor B of the present invention is not particularly restricted as long as the gene encodes the factor B of the present invention as described above. The above description on factor C is also applied *mutatis mutandis* to the variants of the gene and protein.

[0034]

The "factor B activity" means an activity by which factor B becomes active-type factor B in the presence of active-type factor C, to change a proclotting enzyme into its active form, a clotting enzyme. The fact that the

factor B of the present invention "has the factor B activity" can be confirmed, for example, by using the factor B of the present invention in combination with a suitable factor C and a suitable proclotting enzyme, and detecting the progress of the cascade reaction in the presence of endotoxin. More particularly, the protein of SEQ ID NO:2 may be used as the suitable factor C, and the protein of SEQ ID NO:6 may be used as the suitable proclotting enzyme. The progress of the cascade reaction can be measured using the later-mentioned substrate for detection.

[0035]

The proclotting enzyme of the present invention may be a variant of the proclotting enzyme of any of the above-described horseshoe crabs, for example, a variant of the protein having the amino acid sequence shown in SEQ ID NO:6, as long as the proclotting enzyme of the present invention has the proclotting enzyme activity. Further, the gene encoding the proclotting enzyme of the present invention is not particularly restricted as long as the gene encodes the proclotting enzyme of the present invention as described above. The above description on factor C is also applied *mutatis mutandis* to the variants of the gene and protein.

[0036]

The "proclotting enzyme activity" means an activity by which a proclotting enzyme is changed to a clotting enzyme in the presence of active-type factor B, to react

with the later-mentioned substrate for detection. The "activity to react with a substrate for detection" means, for example, an activity to react with coagulogen to cause coagulation, and an activity to react with Boc-Leu-Gly-Arg-pNA to release pNA. The fact that the proclotting enzyme of the present invention "has the proclotting enzyme activity" can be confirmed, for example, by using the clotting enzyme of the present invention in combination with a suitable factor C and a suitable factor B, and detecting the progress of the cascade reaction in the presence of endotoxin. More particularly, the protein of SEQ ID NO:2 may be used as the suitable factor C, and the protein of SEQ ID NO:4 may be used as the suitable factor B. The progress of the cascade reaction can be measured using the later-mentioned substrate for detection.

[0037]

To the factor B of the present invention and/or the proclotting enzyme of the present invention, an arbitrary peptide or the like may be added as long as the factors have the factor B activity and the proclotting enzyme activity, respectively. Examples of such a peptide include tag sequences such as His-tag and V5-tag. Similarly to the factor C of the present invention, the factor B of the present invention and/or the proclotting enzyme of the present invention to be employed may be any of those wherein His-tag is not added to the C-terminus, those wherein V5-tag is not added to the C-terminus,

those wherein no peptide is added to the C-terminus at all, and those wherein no peptide is added to either terminus at all.

[0038]

Further, the combinations of the codons in the gene encoding the factor B of the present invention and/or the gene encoding the proclotting enzyme of the present invention may be modified such that the gene(s) is/are optimized for being expressed in insect cells. Examples of the DNA that encodes the factor B of SEQ ID NO:4 and has combinations of the codons optimized for expression in insect cells include the DNA of SEQ ID NO:8. Examples of the DNA that encodes the proclotting enzyme of SEQ ID NO:6 and has combinations of the codons optimized for expression in insect cells include the DNA of SEQ ID NO:9. Each of the gene encoding the factor B of the present invention and/or the gene encoding the proclotting enzyme of the present invention may be a variant of a DNA whose combinations of the codons are optimized for expression in insect cells.

[0039]

The endotoxin-measuring agent of the present invention may consist of the factor C of the present invention, the factor B of the present invention, and the proclotting enzyme of the present invention.

[0040]

The endotoxin-measuring agent of the present invention may comprise a substrate for detection of the

progress of the cascade reaction. In the present invention, such a substrate may be referred to as "substrate for detection".

[0041]

Examples of the substrate for detection include coagulogen. Due to contact of coagulogen with a clotting enzyme, coagulation occurs to produce coagulin. The progress of the coagulation reaction may be assayed by measuring the turbidity of the reaction solution. Coagulogen can be recovered from a horseshoe crab blood cell extract (lysate). Also, because a nucleotide sequence of the gene encoding coagulogen has been clarified (Miyata, et al., PROTEIN, NUCLEIC ACID AND ENZYME, Extra Edition, No. 29, pp. 30-43 (1986)), coagulogen can be produced according to a conventional method by genetic engineering.

[0042]

As the substrate for detection, a synthetic substrate may also be used. The synthetic substrate is not particularly restricted as long as the substrate has a property suitable for detection, such as a property by which catalytic reaction of a clotting enzyme causes development of color or emission of fluorescence. Examples of the synthetic substrate include substrates represented by the general formula X-Y-Z (wherein X represents a protecting group, Y represents a peptide, and Z represents a dye bound to Y via an amide bond). In cases where endotoxin exists in the reaction system,

catalytic reaction of a clotting enzyme, which is yielded as a result of the cascade reaction, cleaves the amide bond between Y and Z, to release the dye Z, leading to development of color or emission of fluorescence. The protecting group X is not particularly restricted, and a known protecting group for peptides may be suitably used.

Examples of such a protecting group include the t-butoxycarbonyl group and the benzoyl group. The dye Z is not particularly restricted, and may be either a dye which can be detected under visible light or a fluorescent dye. Examples of the dye Z include pNA (para-nitroaniline), MCA (7-methoxycoumarin-4-acetic acid), DNP (2,4-dinitroaniline), and Dansyl dyes. Examples of the peptide Y include Leu-Gly-Arg (LGR), Ile-Glu-Gly-Arg (IEGR) (SEQ ID NO:12), and Val-Pro-Arg (VPR). The released dye Z may be measured by a method selected depending on the property of the dye.

[0043]

Further, the endotoxin-measuring agent of the present invention may also comprise a component other than the factors and the substrate for detection, as long as the agent can be used for measurement of endotoxin. Such a component is not particularly restricted, and may be selected in consideration of preservability, ease of handling, and stability of the factors and the substrate for detection. The endotoxin-measuring agent of the present invention may comprise, for example, a pH-buffering agent and/or salt. Examples of the pH-

buffering agent include HEPES buffer, MES buffer, Tris buffer, and GTA wide-range buffer. Organic solvents such as alcohols, esters, ketones, and amides may also be comprised in the endotoxin-measuring agent of the present invention.

[0044]

The endotoxin-measuring agent of the present invention may be formulated into an arbitrary form including, for example, a solid form, liquid form, and gel form. For the formulation, additives normally used as formulation carriers such as vehicles; binders; disintegrants; lubricants; stabilizers; correctives; diluents; surfactants; and solvents may be used. The endotoxin-measuring agent of the present invention may be used for measuring endotoxin as it is, or after being diluted, dispersed, or dissolved in water, physiological saline, buffer, or the like. Needless to say, the resulting formulation obtained by such dilution, dispersion, or dissolution is also within the scope of the endotoxin-measuring agent of the present invention.

[0045]

In the endotoxin-measuring agent of the present invention, the factors and the other components may exist as a mixture(s) or may separately exist. For example, the factors may be mixed at an arbitrary ratio to be formulated, or may be separately formulated.

[0046]

The concentrations of the factors and the other

components in the endotoxin-measuring agent of the present invention are not particularly restricted, and preferably adjusted such that the concentrations are within the later-mentioned preferred ranges when endotoxin is measured. The concentration of each of the factors in the endotoxin-measuring agent of the present invention (in terms of the solution prepared before contacting with the test sample) is, for example, preferably 20 to 100 $\mu\text{g/mL}$, more preferably 40 to 80 $\mu\text{g/mL}$, especially preferably about 60 $\mu\text{g/mL}$.

[0047]

The endotoxin-measuring agent of the present invention may be provided as an endotoxin-measuring kit. The endotoxin-measuring kit is not particularly restricted as long as the kit contains the endotoxin-measuring agent of the present invention.

[0048]

(2) Method for Producing Endotoxin-measuring Agent of Present Invention

The factors to be comprised in the endotoxin-measuring agent of the present invention can be produced by being expressed using insect cells as a host.

[0049]

The insect cells are not particularly restricted as long as the cells can express the factors, and cells normally used for expression of a heterologous protein may be suitably used. Examples of such insect cells include Sf9, Sf21, SF+, and High-Five. The insect cells

are preferably Sf9.

[0050]

The culture conditions under which the insect cells are cultured are not particularly restricted as long as the insect cells can be cultured under the conditions, and culture conditions normally used for culturing insect cells may be used after, if necessary, appropriately modified. For example, as a culture medium, one normally used for culturing insect cells may be used. Examples of such a medium include commercially available serum-free media for insect cells. More particularly, Sf900 II medium (Invitrogen) or the like may be suitably used. The cultivation may be carried out, for example, at 27°C to 28°C with shaking.

[0051]

The method for expressing the factors using insect cells as a host is not particularly restricted as long as the factors can be expressed thereby, and a method normally used for expression of a heterologous protein can be suitably used. For example, each factor can be expressed by infecting insect cells with a virus into which a gene encoding the factor was incorporated (viral method). Alternatively, each factor can be expressed by introducing a vector, into which a gene encoding the factor was incorporated, into insect cells, thereby incorporating the gene into the chromosome of the host (stably expressing cell line method).

[0052]

<Viral Method>

The virus to be used in the viral method is not particularly restricted as long as insect cells can be infected with the virus and the factors can be expressed thereby, and a virus normally used for expression of a protein in insect cells can be suitably used. Examples of such a virus include baculovirus. The baculovirus is preferably nucleopolyhedrovirus (NPV). Examples of the NPV include AcNPV (*Autographa californica* NPV) and BmNPV (*Bombix mori* NPV). The NPV is preferably AcNPV.

[0053]

Introduction of the nucleic acid into the virus can be carried out by a conventional method, for example, by homologous recombination using a transfer vector. Examples of the transfer vector include pPSC8 (Protein Sciences), pFastBac (Invitrogen), and pVL1393 (Pharmingen). The transfer vector is preferably pPSC8.

[0054]

By infecting, by a conventional method, insect cells with a virus into which the gene encoding each factor was incorporated, insect cells that harbor the virus and express the factor can be obtained.

[0055]

<Stably Expressing Cell Line Method>

By incorporating the gene encoding each factor into the chromosome of insect cells, a stably expressing cell line, which stably expresses the factor, can be obtained.

The method of construction of the stably expressing cell

line is not particularly restricted, and the construction can be carried out by a conventional method. For example, the stably expressing cell line can be constructed using the pIZ/V5-His vector (Invitrogen) according to the manual.

[0056]

In any case, the expressing cells are constructed such that the expressed factor C has the C-terminus to which Histag is not attached. Further, in cases where each factor is to be expressed without addition of any peptide, which is not restricted to His-tag at the C-terminus of the factor C, the expressing cells may be constructed such that no peptide is added.

[0057]

In any case, the factors may be expressed together by a single type of expressing cells, or expressing cells may be constructed for each factor to express the respective factors separately.

[0058]

Whether or not each factor is expressed can be confirmed by measuring the activity of the factor. Whether or not each factor is expressed can also be confirmed by measuring the amount of mRNA transcribed from the gene encoding the factor, or by detecting the factor by Western blotting using an antibody.

[0059]

Each expressed factor may be recovered as a solution containing the factor, to be used as a component of the

endotoxin-measuring agent of the present invention. The solution containing the factor may be, for example, a culture broth, culture supernatant, or cell extract, or a mixture thereof. Each factor may be used either after purification or without purification. In the present invention, an endotoxin-measuring agent having a sufficiently high performance can be provided even by using cell culture supernatant containing each expressed factor as it is without purification of the factor. In cases where each factor is to be purified, the purification may be carried out, for example, by a known method used for purification of a protein. Examples of such a method include ammonium sulfate precipitation, gel filtration chromatography, ion-exchange chromatography, hydrophobic interaction chromatography, and hydroxyapatite chromatography. In cases where a tag such as His-tag is attached to each factor, the factor may also be purified by affinity chromatography using affinity against the tag.

[0060]

In cases where each factor was produced by the viral method, the virus is preferably eliminated. The method of elimination of the virus is not particularly restricted, and the elimination may be carried out by a conventional method. For example, the virus may be eliminated through a hollow-fiber filtration membrane having a pore size of 500 kDa.

[0061]

(3) Method of Present Invention for Measuring Endotoxin.

By mixing the endotoxin-measuring agent of the present invention with a test sample, the cascade reaction proceeds in cases where the test sample contains endotoxin. By measuring the progress of the cascade reaction, the endotoxin in the test sample can be measured. That is, the present invention provides a method for measuring endotoxin in a test sample, which method comprises a step of mixing the endotoxin-measuring agent of the present invention with a test sample, and a step of measuring the progress of the cascade reaction (hereinafter referred to as "first embodiment").

[0062]

In the first embodiment, each factor comprised in the endotoxin-measuring agent of the present invention may have been contained in the reaction system from the beginning of the step of mixing the endotoxin-measuring agent of the present invention with a test sample, or may be sequentially added to the reaction system.

[0063]

For example, the step of mixing the endotoxin-measuring agent of the present invention with a test sample may comprise the following steps (A) to (C):

(A) a step of adding the factor C of the present invention to the reaction system;

(B) a step of adding the factor B of the present invention to the reaction system; and

(C) a step of adding the proclotting enzyme of the

present invention to the reaction system.

[0064]

Steps (A) to (C) may be carried out separately, partially at the same time, or totally at the same time. Steps (A) to (C) may be carried out in an arbitrary order. For example, Step (A) may be followed by Step (B), which may then be followed by Step (C).

[0065]

In the first embodiment, the progress of the cascade reaction can be measured by adding a substrate for detection to the reaction system and then measuring the reaction of the substrate (coloring, coagulation, or the like). The substrate for detection may have been contained in the reaction system from the beginning of the step of mixing the endotoxin-measuring agent of the present invention with a test sample, or may be added to the reaction system during the progress or after completion of the step. The first embodiment, of course, includes cases where the endotoxin-measuring agent of the present invention which preliminarily contains a substrate for detection is employed.

[0066]

As long as the cascade reaction proceeds in cases where endotoxin is contained in the test substance, the factor B and the proclotting enzyme of the present invention themselves may not necessarily contact with the test sample. That is, another embodiment of the method of the present invention for measuring endotoxin

(hereinafter referred to as "second embodiment") is a method for measuring endotoxin in a test substance, which method comprises Steps (A) to (D) below.

(A) a step of mixing the factor C of the present invention with a test sample;

(B) a step of mixing the factor B of the present invention with the factor C after the mixing thereof in Step A;

(C) a step of mixing the proclotting enzyme of the present invention with the factor B after the mixing thereof in Step B; and

(D) a step of measuring the progress of the cascade reaction.

[0067]

In the second embodiment, Steps (A) to (D) may proceed separately, partially at the same time, or totally at the same time. For example, after beginning Step A, the factor B and/or proclotting enzyme may be added to the reaction system during the progress or after completion of the step. Alternatively, after beginning Step B, the proclotting enzyme may be added to the reaction system during the progress or after completion of the step. Alternatively, all the 3 factors may be contained in the reaction system from the beginning of Step A. Alternatively, for example, the factor C after the contacting in Step A may be recovered to be used in Step B, and the factor B after the contacting in Step B may be recovered to be used in Step C.

[0068]

In the second embodiment, the progress of the cascade reaction may be measured by adding a substrate for detection to the reaction system and then measuring reaction of the substrate (coloring, coagulation, or the like). The substrate for detection may be contained in the reaction system from the beginning of Step A, or may be added to the reaction system during the progress or after completion of each step.

[0069]

The method of the present invention for measuring endotoxin may comprise another arbitrary step as long as the cascade reaction proceeds in cases where the test sample contains endotoxin. For example, the method of the present invention for measuring endotoxin may comprise a step of adding a substrate for detection to the reaction system, or a step of mixing a clotting enzyme produced by the cascade reaction with a substrate for detection. Further, for example, the method of the present invention for measuring endotoxin may comprise a step of calculating the endotoxin level in the test sample on the basis of reaction of the substrate for detection.

[0070]

In the method of the present invention for measuring endotoxin, the reaction is preferably carried out in an aqueous solvent such as water or a buffer.

[0071]

In the method of the present invention for measuring endotoxin, the concentration of each factor in the reaction solution is not particularly restricted as long as the cascade reaction proceeds in cases where endotoxin is contained in the test sample, and may be set appropriately depending on the property of the factor and/or the like. For example, the concentration of each factor is usually 10 to 50 $\mu\text{g/mL}$, preferably 20 to 40 $\mu\text{g/mL}$, more preferably about 30 $\mu\text{g/mL}$, in terms of the final concentration.

[0072]

In the method of the present invention for measuring endotoxin, the concentration of the substrate for detection in the reaction solution is not particularly restricted as long as the cascade reaction proceeds in cases where endotoxin is contained in the test sample, and may be set appropriately depending on the property of the substrate for detection and/or the like. For example, in cases where the substrate for detection is a synthetic substrate, the concentration of the substrate for detection is usually 0.001 mM to 100 mM, preferably 0.01 mM to 10 mM, in terms of the final concentration.

[0073]

In any embodiment, the reaction system may contain an arbitrary component(s) other than the endotoxin-measuring agent in the first embodiment or the factors in the second embodiment, substrate for detection, and test sample, as long as the cascade reaction proceeds in cases

where endotoxin is contained in the test sample. For example, the reaction system may contain a pH-buffering agent and/or salt. Examples of the pH-buffering agent include HEPES buffer, MES buffer, Tris buffer, and GTA wide-range buffer. Organic solvents such as alcohols, esters, ketones, and amides may also be contained in the reaction system.

[0074]

The pH of the reaction solution is not particularly restricted as long as the cascade reaction proceeds in cases where endotoxin is contained in the test sample, and may be set appropriately depending on the property of each factor. For example, the pH of the reaction solution is usually 5 to 10, preferably 7 to 8.5.

[0075]

The reaction temperature is not particularly restricted as long as the cascade reaction proceeds in cases where endotoxin is contained in the test sample, and may be set appropriately depending on the property of each factor. The reaction temperature is, for example, usually 10°C to 80°C, preferably 20°C to 50°C. For example, the reaction temperature may be room temperature.

[0076]

The reaction time is not particularly restricted, and may be set appropriately depending on conditions such as the property of each factor and the reaction temperature. The reaction time is, for example, usually 5 minutes to 1

hour, preferably 15 minutes to 45 minutes. For example, the reaction time may be 30 minutes.

[0077]

In any embodiment, during the process of reaction, the test sample, factors, and other components may be additionally added, individually or in an arbitrary combination, to the reaction system. These components may be added at once or in a plurality of times, or may be added continuously. Constant conditions may be employed from the beginning of the reaction to the end of the reaction, or conditions may be changed during the process of reaction.

[0078]

By measuring reaction of the substrate for detection (coloring, coagulation, or the like), the progress of the cascade reaction due to existence of endotoxin can be measured, and hence the endotoxin in the test substance can be measured. The reaction of the substrate for detection (coloring, coagulation, or the like) may be measured by a method depending on the substrate for detection employed.

[0079]

In cases where the measurement of endotoxin is carried out quantitatively, an endotoxin standard sample whose concentration is known may be used to obtain a correlation data between the endotoxin level and the degree of reaction of the substrate for detection (degree of coloring, coagulation, or the like), and, endotoxin

existing in the test sample may be quantified on the basis of the correlation data. The correlation data may be, for example, a calibration curve. The quantification may be carried out either by the kinetic method or by the end point method.

[0080]

The test sample to be subjected to the measurement of endotoxin is not particularly restricted, and examples thereof include medical water, pharmaceuticals, infusion solutions, blood preparations, medical equipments, medical apparatuses, cosmetics, foods and beverages, environmental samples (e.g., airs, rivers, and soils), biological components (e.g., bloods, body fluids, and tissues), naturally occurring proteins, recombinant proteins, nucleic acids, and carbohydrates. The test sample may be subjected to the measurement of endotoxin by mixing, dispersing, or dissolving the test sample as it is or an extract or washing solution of the test sample in a reaction system.

EXAMPLES

[0081]

The present invention will now be described by way of Examples more particularly. However, these are merely examples of the present invention, and the scope of the present invention is not limited to these.

[0082]

Example 1: Production of Endotoxin-measuring Agent of

Present Invention

(1-1) Method Using Virus (hereinafter referred to as "viral method")

In the present Example, a recombinant baculovirus into which the gene encoding each of factor C, factor B, and a proclotting enzyme was incorporated was used to express the factor in insect cells, and an endotoxin-measuring agent was thereby produced.

[0083]

(1-1-1) Preparation of Recombinant Baculovirus

As a DNA encoding His-tag-attached factor C (His-tag-attached factor C gene), the DNA of SEQ ID NO:7 was totally synthesized using a generally available contract service (TAKARA BIO INC.). The His-tag-attached factor C is the factor C of a Japanese horseshoe crab shown in SEQ ID NO:2 wherein a 6×His-tag is attached to the C-terminus. The DNA was inserted between the recognition sites of restriction enzymes *NruI* and *SmaI* of a transfer vector pPSC8 (Protein Sciences), to obtain a vector for recombination. Using the vector for recombination, the His-tag-attached factor C gene was incorporated into a baculovirus AcNPV, to prepare a recombinant baculovirus.

[0084]

Further, using a primer FC-N-Pst (SEQ ID NO:10) and a primer FC-notag-R-Bam (SEQ ID NO:11), and the above-described DNA encoding the His-tag-attached factor C as a template, PCR was carried out to prepare a DNA encoding factor C wherein the nucleotide sequence encoding the

His-tag sequence at the 3'-end was removed (His-tag-free factor C gene). The DNA encodes the Japanese horseshoe crab factor C shown in SEQ ID NO:2, wherein no His tag is attached at the C-terminus. Also for the His-tag-free factor C gene, a recombinant baculovirus was prepared by the same method as described above.

[0085]

As a DNA encoding factor B (factor B gene), the DNA of SEQ ID NO:8 was totally synthesized using a generally available contract service (TAKARA BIO INC.). The DNA encodes the Japanese horseshoe crab factor B shown in SEQ ID NO:4 (His-tag free), and the combinations of its codons are optimized for expression in insect cells. Also for the factor B gene, a recombinant baculovirus was prepared by the same method as described above. However, the position of insertion in the pPSC8 vector was between the recognition sites of restriction enzymes *Pst*I and *Kpn*I.

[0086]

As a DNA encoding the proclotting enzyme (proclotting enzyme gene), the DNA of SEQ ID NO:9 was totally synthesized using a generally available contract service (TAKARA BIO INC.). The DNA encodes the Japanese horseshoe crab proclotting enzyme shown in SEQ ID NO:6 (His-tag free), and the combinations of its codons are optimized for expression in insect cells. Also for the proclotting enzyme gene, a recombinant baculovirus was prepared by the same method as described above. However,

the position of insertion in the pPSC8 vector was between the recognition sites of restriction enzymes XbaI and BglII.

[0087]

(1-1-2) Infection of Insect Cells (Sf9 Cells) with Recombinant Baculovirus

Sf9 cells (Novagen) were inoculated in a medium at 1.5×10^6 cells/mL, and the recombinant baculovirus, into which the DNA encoding the His-tag-attached factor C was introduced, was added to the medium, to infect the cells with the virus. As the medium for the Sf9 cells, Sf900 II medium (Invitrogen) supplemented with antibiotics (antibiotics-antifungal agents ($\times 100$); Invitrogen) (final concentration, $\times 1$) (1 L) was used. The multiplicity of infection (MOI) of the virus was set to 1.0. Thereafter, the obtained cells were cultured at 28°C for 48 hours with shaking.

[0088]

Similarly, Sf9 cells were infected with the virus into which the DNA encoding the His-tag-free factor C was introduced.

[0089]

Further, Sf9 cells were infected also with each of the virus to which the DNA encoding the factor B was introduced and the virus to which the DNA encoding the proclotting enzyme was introduced. In these cases, MOI was set to 0.5, and the culturing time was 72 hours.

[0090]

(1-1-3) Recovery of Solution of Expressed Recombinant Protein

Each of the culture broths obtained after the above culturing was centrifuged at 4°C at 3000×g for 30 minutes to obtain the supernatant, which was then stored at -80°C.

[0091]

(1-1-4) Removal of Impurities and Viruses from Recombinant Protein Solution

Each of the supernatants which had been stored frozen as described above was thawed, and applied to a filter having a pore size of 0.1 µm (Cup Filter (Millipore)). Filtration was carried out with suction, and the solution which had passed through the filter was recovered. Each recovered supernatant was applied to a hollow fiber filtration membrane having a pore size of 500 kDa (polyether sulfone hollow fiber membrane; Spectrum Labs) and filtered using the Kros Flow TFF pump filtration system (Spectrum Labs). Each solution which had passed through the membrane was recovered.

[0092]

(1-1-5) Preparation of Reagent

At 4°C, 560 mL of each solution obtained in the above (1-1-4) (wherein factor C, factor B, or proclotting enzyme is contained), 134 mL of distilled water, 126 mL of 6.66 mM aqueous solution of a synthetic substrate (Boc-Leu-Gly-Arg-pNA) (final concentration, 0.3 mM) and 560 mL of 15% aqueous dextran solution (final

concentration, 3%) were mixed together. This mixture was aliquoted in 5 mL-volumes into vials and freeze-dried, to provide the endotoxin-measuring agent 1.

[0093]

(1-2) Method Using Plasmid (hereinafter also referred to as "stably expressing cell line method")

In the present Example, a gene encoding each of the factor C, factor B, and proclotting enzyme was incorporated into the chromosome of insect cells to construct a stably expressing cell line, and each factor was then expressed, thereby producing an endotoxin-measuring agent.

[0094]

(1-2-1) Preparation and Cultivation of Stably Expressing Cell Line

Each of the His-tag-free factor C gene, factor B gene (SEQ ID NO:8), and proclotting enzyme gene (SEQ ID NO:9) used in the above-described viral method was introduced into Sf9 cells (Invitrogen) using the pIZ vector kit (Invitrogen).

[0095]

More particularly, each of the DNAs was firstly incorporated between the *EcoRV* and *MluI* recognition sites in a vector pIZ/V5-His comprised in the kit, and the resulting each vector was mixed with Cellfectin comprised in the kit, followed by introduction of the vector into Sf9 cells. The position of incorporation of the DNAs in pIZ/V5-His, and the like are shown in Fig. 2. In the

region indicated by a thick arrow shown at the top in Fig. 2, each one of the DNAs was incorporated. As the medium for the Sf9 cells, Sf900 III medium (Invitrogen) supplemented with antibiotics (antibiotics-antifungal agents ($\times 100$); Invitrogen) (final concentration, $\times 1$) and Zeocin antibiotic (Invitrogen) (final concentration, 50 $\mu\text{g/mL}$) was used. The density of the thus obtained cell line, into which each DNA was introduced, was adjusted to 6×10^5 cells/mL (1L) in the medium, and the cells were cultured at 28°C for 96 hours with shaking.

[0096]

It should be noted that, although a His tag sequence is contained in pIZ/V5-His, all of the above described DNAs have a stop codon, so that all of the factor C, factor B, and proclotting enzyme are expressed without addition of His-tag.

[0097]

(1-2-2) Recovery of Solution of Recombinant Protein,
Removal of Impurities, and Preparation of Reagent

Each culture broth obtained after the above-described culturing was processed in the same manner as described in "(1-1-3) Recovery of Solution of Expressed Recombinant Protein", "(1-1-4) Removal of Impurities and Viruses from Recombinant Protein Solution" and "(1-1-5) Preparation of Reagent" for the viral method. However, the process of filtration using a hollow fiber filtration membrane in "(1-1-4) Removal of Impurities and Viruses from Recombinant Protein Solution" was not carried out. The

thus obtained measuring agent was provided as the endotoxin-measuring agent 2.

[0098]

Example 2: Properties and the Like of Expressed Proteins
(2-1) Comparison of Expression Level of Factor C

The expression level was compared among the His-tag-free factor Cs obtained by the viral method and the stably expressing cell line method, and the His-tag-attached factor C obtained by the viral method.

[0099]

The expression level was evaluated by sampling 0.5, 1.5, 5, or 15 μ L of the solution corresponding to the one after the filtration and before the preparation of the reagent in Example 1 and subjecting the sampled solutions to 5-20% polyacrylamide gel electrophoresis (under non-reducing conditions) in the presence of SDS and then to Western blotting using an anti-factor C antibody (2C12, obtained from Prof. Shun-ichiro Kawabata, Department of Biology, Graduate School of Sciences, Kyushu University).

[0100]

The results are shown in Fig. 3. The results indicate that the expression levels of the His-tag-free factor Cs were lower than the expression level of the His-tag-attached factor C. Further, the intensities of the bands on the Western blot in Fig. 3 were measured using a densitometer, and, the volume ratio of each solution with which equal concentrations of the factor Cs are attained was calculated on the basis of relative

values of the measured intensities. The volume ratio was 50 as for the His-tag free factor C obtained by the viral method, 17 as for the His-tag free factor C obtained by the stably expressing cell line method, and 7 as for the His-tag-attached factor C obtained by the viral method.

[0101]

(2-2) Comparison of Activity of Factor C

The proclotting enzyme-activating capacity of each of the factor C solutions was studied using an equal amount of factor C.

[0102]

More particularly, each of the His-tag-attached factor C solution obtained by the viral method (0.7 μ L or 5 μ L), His-tag-free factor C solution obtained by the viral method (5 μ L), and His-tag-free factor C solution obtained by the stably expressing cell line method (1.7 μ L) was placed in a well of a 96-well plate. Thereafter, the factor B-containing solution (5 μ L) and the proclotting enzyme-containing solution (5 μ L) obtained after the filtration through the 0.1 μ m filter in (1-1-4) in the viral method in Example 1, and Boc-Leu-Gly-Arg-pNA (final concentration, 0.3 mM), Tris-HCl (pH 8.0) (final concentration, 100 mM), and 50 μ L of endotoxin (product name "USP-Reference Standard Endotoxin" (USP-RSE); commercially available from Seikagaku Biobusiness Corporation) (sample concentration: 0, 0.05, or 0.5 EU/mL) were added to each well such that the total volume in the well became 100 μ L, and mixed together, followed

by incubation at 37°C for 3 hours, during which the absorbance at 405 nm was measured with time. As a negative control, distilled water was used. The rate of increase in the absorbance (the absorbance change rate) reflects the proclotting enzyme-activating capacity. The term "EU" means the "endotoxin unit", which is a unit representing the amount of endotoxin (this also applies hereinafter).

[0103]

The results are shown in Fig. 4. In Fig. 4, "DW" means distilled water; "Virus + His tag (x1)" means the His-tag-attached factor C solution obtained by the viral method (0.7 µL); "Virus + His tag (x7)" means the same solution (5 µL); "Virus No tag (x1)" means the His-tag free factor C solution obtained by the viral method; and "Stable Sf9 No tag (x1)" means the His-tag free factor C solution obtained by the stably expressing cell line method.

[0104]

As a result, activation of the proclotting enzyme was not observed or hardly observed in the His-tag-attached factor C solution containing the equal amount of factor C (0.7 µL), and even in the solution containing about 7 times the amount of factor C (5 µL). On the other hand, the His-tag-free factor C showed a remarkable proclotting enzyme-activating capacity irrespective of whether it was obtained by the viral method or by the stably expressing cell line method.

[0105]

From the above results, it was shown that a recombinant factor C molecule expressed without addition of His-tag sequence has a much stronger proclotting enzyme-activating capacity than a recombinant factor C molecule expressed with addition of His-tag sequence. Further, it was shown that each of the expressed proteins can be used without purification, in the state where the protein is contained in the culture supernatant.

[0106]

(2-3) Comparison of Stability of Expressed Factor C

(2-3-1) Stability of Factor C Expressed by Viral Method

In the step of culturing the virus-infected cells at 28°C with shaking in (1-1-2) in the viral method in Example 1, the supernatant was recovered after 48 hours, 72 hours, and 96 hours of cultivation, and each recovered supernatant was subjected to 5-20% polyacrylamide gel electrophoresis (under non-reducing conditions) in the presence of SDS, followed by evaluation of the remaining amount of the factor C by Western blotting using the anti-factor C antibody (2C12, which is the same as the one used above). Further, sampling and analysis were separately carried out in the same manner for the supernatant obtained by adding a protease inhibitor (leupeptin at a final concentration of 0.5 µg/mL + pepstatin A at a final concentration of 0.7 µg/mL) to the culture broth after 24 hours of the infection with the virus.

[0107]

The results are shown in Fig. 5. As a result, it was shown that the factor C expressed by the viral method was decomposed with time during the cultivation. Further, it was shown that decomposition of the factor C also occurred to some extent in the case where the protease inhibitor was added.

[0108]

(2-3-2) Stability of Factor C Expressed by Stably Expressing Cell Line Method

Similarly, in the step of culturing the stably expressing cell line at 28°C with shaking in (1-2-1) in the stably expressing cell line method in Example 1, the supernatant was recovered after 72 hours, 96 hours, 120 hours, 144 hours, and 168 hours of cultivation, and each recovered supernatant was subjected to 5-20% polyacrylamide gel electrophoresis (under non-reducing conditions) in the presence of SDS, followed by evaluation of the remaining amount of the factor C by Western blotting using the anti-factor C antibody (2C12, which is the same as the one used above). Further, the supernatant obtained after 48 hours of cultivation by the viral method was also applied.

[0109]

The results are shown in Fig. 6. As a result, the factor C expressed by the stably expressing cell line method has not been decomposed in the absence of a protease inhibitor even after 168 hours of cultivation.

By this, it was shown that use of the stable expressing cell line method can prevent decomposition of factor C.

[0110]

(2-4) Study on Whether Treatment by Hollow Fiber Membrane Filtration Is Necessary

Whether the treatment by a hollow fiber filtration membrane in (1-1-4) in the viral method is necessary was studied. Using each solution sampled before filtration through the hollow fiber membrane in (1-1-4) and each solution sampled after filtration therethrough (3 lots) in (1-1-4), the rate of increase in the absorbance (the absorbance change rate) was measured in the same manner as in the above (2-2), by adding endotoxin (USP-RSE) to a final concentration of 0 or 0.05 EU/mL.

[0111]

The results are shown in Fig. 7. In Fig. 7, "unfiltered solution" means a solution remained in the hollow fiber membrane cartridge without being filtered. In the cases where each solution sampled after filtration through the hollow fiber membrane was used, the degree of activation of the proclotting enzyme was low when the concentration of endotoxin was 0 EU/mL (in other words, the blank value upon endotoxin measurement was low), and that is, an excellent result was obtained. By contrast, it was revealed that, in the cases where each solution sampled before filtration through the hollow fiber membrane ("before filtration" or "unfiltered solution") was used, the degree of activation of the proclotting

enzyme was high even in the cases of 0 EU/mL of endotoxin, which leads to a high blank value upon endotoxin measurement.

[0112]

By contrast, by the stably expressing cell line method, the degree of activation of the proclotting enzyme in the case of 0 EU/mL of endotoxin (the blank value upon endotoxin measurement) was kept low even without such a process of filtration through the hollow fiber filtration membrane (Fig. 4).

[0113]

From these results, it was shown that, while filtration through a hollow fiber filtration membrane is indispensable in cases where the viral method is used, such filtration is not necessary in cases where the stably expressing cell line method is used.

[0114]

Example 3: Measurement of Endotoxin Using Endotoxin-Measuring Agent of Present Invention

(3-1) Measurement Using Endotoxin-measuring Agent 1

To the endotoxin-measuring agent 1 (freeze-dried product), 3.3 mL of 100 mM Tris buffer (pH 8.0) was added, to dissolve the agent. In this solution, the protein concentration of each of the culture supernatants containing the factor C, factor B, and proclotting enzyme was about 60 µg/mL.

Into each well of a 96-well microtiter plate, 50 µL of an endotoxin solution at a concentration of 0, 0.001,

0.01, or 0.1 EU/mL was aliquoted, and 50 μ L of the endotoxin-measuring agent solution prepared by dissolving the agent was added to the each well, followed by mixing the resulting mixture. The mixture was then incubated at 37°C for 30 minutes, and the endotoxin concentration was measured according to the reaction rate method in which the absorbance at 405 nm was measured with time during the incubation. In this reaction solution, the protein concentration of each of the culture supernatants containing the factor C, factor B, and proclotting enzyme was about 30 μ g/mL.

[0115]

The results are shown in Fig. 8. As a result, it was shown that, in cases where the factors expressed by the viral method are used, the absorbance change rate linearly increases within the range of 0.001 to 0.10 EU/mL as the concentration of endotoxin increases.

[0116]

(3-2) Measurement Using Endotoxin-measuring Agent 2

To the endotoxin-measuring agent 2 (freeze-dried product), 3.3 mL of 100 mM Hepes buffer (pH 7.6) was added, to dissolve the agent. In this solution, the protein concentration of each of the culture supernatants containing the factor C, factor B, and proclotting enzyme was about 60 μ g/mL.

Into each well of a 96-well microtiter plate, 50 μ L of an endotoxin solution at a concentration of 0, 0.0005, 0.001, 0.005, 0.01, or 0.1 EU/mL was aliquoted, and 50 μ L

of the endotoxin-measuring agent solution prepared by dissolving the agent was added to the each well, followed by mixing the resulting mixture. The mixture was then incubated at 37°C for 30 minutes, and the endotoxin concentration was measured according to the reaction rate method in which the absorbance at 405 nm was measured with time during the incubation. In this reaction solution, the protein concentration of each of the culture supernatants containing the factor C, factor B, and proclotting enzyme was about 30 µg/mL.

[0117]

The results are shown in Fig. 9. As a result, it was shown that, in cases where the factors expressed by the stably expressing cell method are used, the absorbance change rate linearly increases within the range of 0.0005 to 0.1 EU/mL as the concentration of endotoxin increases.

[0118]

Based on the above results, with either of the endotoxin-measuring agents, quantification of endotoxin at a concentration of 0.001 EU/mL was possible within 30 minutes. Further, with the endotoxin-measuring agent 2, endotoxin at a concentration of 0.0005 EU/mL was able to be measured within 30 minutes. Thus, it was shown that the endotoxin-measuring agents of the present invention enable more rapid and sensitive quantification of endotoxin compared to the conventional methods (by which the measurement takes not less than 1 hour, and the detection sensitivity of 0.001 EU/mL has not been

achieved). Further, it was shown that, in either case, the expressed factors can be used for a measuring agent as they are without purification.

[0119]

Example 4: Difference in Activity between Recombinant Factor C Protein and Naturally Occurring Factor C Protein
(4-1) Purification of Recombinant Factor C Protein and Naturally Occurring Factor C Protein

By covalently bonding 2 mg of the anti-factor C antibody (2C12, which is the same as the one used above) to sepharose column 1ml (GE Healthcare), 2 factor-C antibody columns were prepared. The preparation was carried out according to the method described in the attached instructions. To 76 mL of culture supernatant containing recombinant factor C protein derived by the stably expressing cell method that was prepared by the same process as described in the above "(1-2-2) Recovery of Recombinant Protein", an equal amount of 20 mM Tris-HCl buffer (pH 8.0) containing 2 M sodium chloride and 2 mM EDTA was added to dilute the culture supernatant, followed by subjecting the resulting dilution to one of the factor-C antibody columns. Similarly, to 76 mL of an extract of horseshoe crab blood cells, an equal amount of 20 mM Tris-HCl buffer (pH 8.0) containing 2 M sodium chloride and 2 mM EDTA was added to dilute the extract, followed by subjecting the resulting dilution to the other of the factor-C antibody columns. The both columns were washed sequentially with 20 mL each of 20 mM Tris-

HCl buffer (pH 8.0) containing 200 mM or 450 mM sodium chloride, and elution was then carried out with 50 mM glycine buffer (pH 2.5). Into a 1.5 mL tube in which 0.025 mL of 1M Trizma base (Sigma) was preliminarily placed, 1 mL of each eluted fraction was collected, to return the pH of the eluted solution to neutral.

[0120]

(4-2) Comparison of Concentration between Purified Recombinant and Naturally Occurring Factor C Proteins

The eluted fractions of the purified recombinant and naturally occurring factor C proteins were subjected to separation by 5-20% polyacrylamide gel electrophoresis (under non-reducing conditions) in the presence of SDS. In this process, purified bovine serum albumin (=BSA) whose concentration is known was also subjected to separation on the same gel as samples for concentration reference (Fig. 10). The intensities of BSA bands on the gel stained with Coomassie brilliant blue were quantified with a densitometer, and plotted against the concentrations of the BSA protein, to prepare a calibration curve (Fig. 11). Based on the band intensities of the purified factor C proteins and the calibration curve, the concentrations of the purified factor C proteins were approximated. As a result, it was revealed that, as for the purified samples, the naturally occurring factor C protein had about 4 times the concentration of the recombinant factor C protein.

[0121]

(4-3) Comparison of Activity between Purified Recombinant and Naturally Occurring Factor C Proteins

A comparison of the activity was made using the purified recombinant and naturally occurring factor C proteins. In this comparison, the protein concentration was equalized between the purified factor Cs based on the results of (4-2). Into each well of a 96-well microtiter plate, 50 μ L of an endotoxin solution at a concentration of 0, 0.05, 0.1, or 0.5 EU/mL was aliquoted. Reagents and culture supernatants were added to the each well such that 50 mM Tris buffer (pH 8.0), 0.2 μ g/mL purified factor C protein, 30 μ g/mL protein of each of culture supernatants containing the recombinant factor B and recombinant proclotting enzyme, and 0.3 mM of the synthetic substrate Boc-Leu-Gly-Arg-pNA were contained in the reaction solution, whose total volume was adjusted to 100 μ L by addition of water for injection. The reaction solution was incubated at 37°C for 30 minutes, and the analysis was carried out according to the reaction rate method in which the absorbance at 405 nm was measured with time during the incubation.

[0122]

As a result, it was revealed that the purified recombinant factor C protein had about twice the activity of the purified naturally occurring factor C protein (Fig. 12). The above results suggest that the recombinant factor C has a higher specific activity than the naturally occurring factor C.

INDUSTRIAL APPLICABILITY

[0123]

By the present invention, endotoxin can be rapidly and highly sensitively measured. Further, by the present invention, an endotoxin-measuring agent can be simply and rapidly produced at a low cost. Therefore, the present invention can be extremely effectively used for detection of endotoxin.

[0124]

DESCRIPTION OF SEQUENCE LISTING

SEQ ID NO:1 DNA sequence of factor C gene of Japanese horseshoe crab

SEQ ID NO:2 Amino acid sequence of factor C of Japanese horseshoe crab

SEQ ID NO:3 DNA sequence of factor B gene of Japanese horseshoe crab

SEQ ID NO:4 Amino acid sequence of factor B of Japanese horseshoe crab

SEQ ID NO:5 DNA sequence of proclotting enzyme gene of Japanese horseshoe crab

SEQ ID NO:6 Amino acid sequence of proclotting enzyme of Japanese horseshoe crab

SEQ ID NO:7 DNA sequence of His-tag-attached factor C gene

SEQ ID NO:8 DNA sequence of factor B gene whose codons are optimized for expression in insect cells

SEQ ID NO:9 DNA sequence of proclotting enzyme gene

whose codons are optimized for expression in insect cells

SEQ ID NO:10 Primer for preparation of His-tag-free
factor C gene

SEQ ID NO:11 Primer for preparation of His-tag-free
factor C gene

SEQ ID NO:12 Peptide sequence

CLAIMS

1. A method for producing a horseshoe crab Factor C comprising an amino acid sequence shown in SEQ ID NO: 2 or having an identity not less than 90% to the full length of the amino acid sequence shown in SEQ ID NO:2 and having factor C activity, which is a recombinant protein which does not have a His-tag sequence at the C-terminus or any other peptide at either terminus and is obtained from insect cells as a host:

the method comprising the steps (A) to (D) below:

(A) a step of incorporating DNA encoding the amino acid sequence of the Factor C into a viral DNA;

(B) a step of infecting insect cells with the virus into which said DNA was incorporated;

(C) a step of allowing insect cells infected with said virus to express the protein encoded by said DNA; and

(D) a step of recovering the Factor C as a solution and eliminating the virus using a hollow fibre filtration membrane having a pore size of 500 kDa.

2. A method for producing a horseshoe crab Factor C comprising an amino acid sequence shown in SEQ ID NO: 2 or having an identity not less than 90% to the full length of the amino acid sequence shown in SEQ ID NO:2 and having factor C activity, which is a recombinant protein which does not have a His-tag sequence at the C-terminus or any other peptide at either terminus and is obtained from insect cells as a host:

the method comprising the steps (A) to (D) below:

(A) a step of incorporating DNA encoding the amino acid sequence of the Factor C into a vector;

(B) a step of introducing the vector, into which said DNA was

incorporated, into insect cells to incorporate said DNA into the chromosome of the insect cells;

(C) a step of allowing the insect cells, into which said DNA was incorporated, to express the protein encoded by said DNA; and

(D) a step of recovering the Factor C as a solution.