

Description

Novel Recombinant Factor C and Method for Producing the Same,
and Method for Measuring Endotoxin

Technical Field

[0001]

The present invention relates to a novel recombinant Factor C, to a method for producing the recombinant Factor C, and to a method for measuring endotoxin.

Background Art

[0002]

Endotoxin is a lipopolysaccharide which is present in the outer membrane of Gram-negative bacteria and is known as a strong pyrogen. It is also known that even a very small amount of endotoxin causes various pathological conditions via bacterial infection. Such conditions include not only fever but also release of an inflammatory cytokine concomitant with activation of macrophages, induction of endotoxin shock, and the like. Therefore, detection of endotoxin is essential in pharmaceutical products such as an injection, water, medical devices, and the like. From another aspect, endotoxin is a conceivable main cause for a shock involved in an infection with a Gram-negative bacterium. Thus, the presence of infection and a therapeutic effect can be determined through a blood endotoxin analysis.

[0003]

Meanwhile, it has been known that the American horseshoe crab (*Limulus polyphemus*) undergoes blood clotting when it is infected with a Gram-negative bacterium. This phenomenon has been conventionally employed for the detection of endotoxin.

[0004]

Specifically, there is known a method for measuring endotoxin by use of a hematocyte extract of a horseshoe crab (i.e. an amebocyte lysate of a horseshoe crab, hereinafter also referred to simply as a lysate) (see, for example, Non-Patent Document 1). This method is called a "limulus test," which employs a cascade reaction of a variety of proteins present in the lysate, which reaction occurs via contact between endotoxin and the lysate. Fig. 1 shows the scheme of the cascade reaction.

[0005]

When endotoxin comes into contact with the lysate, Factor C, which is a serine protease zymogen present in the lysate, is activated to thereby form activated Factor C. The thus-formed activated Factor C activates Factor B present in the lysate, to thereby form activated Factor B. The thus-formed activated Factor B activates Pro-clotting enzyme present in the lysate, to thereby form a corresponding Clotting enzyme.

[0006]

The Clotting enzyme hydrolyzes a specific site of a

coagulogen molecule present in the lysate, thereby coagulin gel is formed, and thus the lysate is coagulated. Thus, endotoxin can be measured through measuring the lysate coagulation reaction.

[0007]

Alternatively, endotoxin may also be measured through coloring reaction between the Clotting enzyme and a synthetic substrate. For example, the Clotting enzyme acts on t-butoxycarbonyl-leucyl-glycyl-arginyl-pNA (Boc-Leu-Gly-Arg-pNA), which is a synthetic substrate, to hydrolyze the amino bonds thereof, and thereby pNA is released. Thus, when the synthetic substrate has been added to the reaction system, endotoxin can be measured through measuring the absorbance (at 405 nm) of the coloring substance (pNA).

[0008]

Furthermore, it is known that a cascade reaction system can be reconstituted by use of Factor C, Factor B, and Pro-clotting enzyme, which are purified from a lysate of the Japanese horseshoe crab (Non-Patent Document 2).

[0009]

However, for using such a lysate, or Factor C, Factor B, and Pro-clotting enzyme purified from the lysate, horseshoe crabs must be caught and blood must be recovered there from. Hence, from the viewpoint of protection of biological resources, difficulty is encountered in supply of such ingredients in an inexhaustible manner. Under such circumstances, there is demand for a technique that can

produce these ingredients by genetic engineering, to thereby reconstitute a cascade reaction system.

[0010]

For example, there is known a case where Factor C, Factor B, and Pro-clotting enzyme were expressed in insect cells as host cells, to thereby reconstitute a cascade reaction system (Patent Documents 1 and 2). However, it has been reported that since the reconstituted system contains sodium chloride, magnesium sulfate, or calcium chloride in the reaction system, the cascade reaction is suppressed (Patent Document 1).

[0011]

Alternatively, there is known a case of using mammalian cells as host cells, wherein Factor C derived from the Singaporean horseshoe crab (*Carcinoscorpius rotundicauda*) was expressed in COS-1, which is a cell line derived from African green monkey kidney cells, as host cells. However, it has been reported that when COS-1 was used as a host, the expressed Factor C was insoluble (Non-Patent Documents 3 and 4). That is, there has never been known a case where functional Factor C is produced using mammalian cells as host cells.

Prior Art Documents

Patent Documents

[0012]

Patent Document 1: WO 2008/004674, pamphlet

Patent Document 2: WO 2012/118226, pamphlet

Non-Patent Documents

[0013]

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

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

Non-Patent Document 3: Roopashree S. Dwarakanath, *et al.*, Biotechnology letters 19(4): 357-361 (1997)

Non-Patent Document 4: Jing Wang, Bow Ho and Jeak L. Ding, Biotechnology letters 23: 71-76 (2001)

Summary of the Invention

Problems to be Solved by the Invention

[0014]

An object of the present invention is to provide a novel recombinant horseshoe crab Factor C, and a method for producing the recombinant Factor C.

[0015]

Meanwhile, injections to be administered in vivo generally contain a variety of salts (ions). In production of such injections, detection of endotoxin is obligated by the pharmacopoeia of the relevant country. Under such circumstances, in an aspect, another object of the present invention is to provide a reconstituted cascade reaction system which is not susceptible to reaction inhibition even in the presence of a salt (ion).

Means for Solving the Problems

[0016]

The present inventors have found that a recombinant horseshoe crab Factor C can be produced by use of human cells or Chinese hamster cells as host cells, and that endotoxin can be measured by use of the thus-produced recombinant Factor C while reaction inhibition in the presence of a salt (ion) is mitigated. The present invention has been accomplished on the basis of these findings.

[0017]

Accordingly, the present invention encompasses the following modes.

[1]

A horseshoe crab Factor C having activity of Factor C.

[1.1.1]

The above-described Factor C, which contains sialic acid.

[1.1.2]

The above-described Factor C, which contains (α -2,3) linked terminal sialic acid.

[1.1.3]

The above-described Factor C, which contains (α -2,3) linked terminal sialic acid in a greater amount, as compared with a native Factor C.

[1.1.4]

The above-described Factor C, which contains (α -2,3)

linked terminal sialic acid in a greater amount, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell.

[1.1.5]

The above-described Factor C, which exhibits a higher reactivity in lectin blotting by use of *Maackia amurensis* agglutinin, as compared with a native Factor C.

[1.1.6]

The above-described Factor C, which exhibits a higher reactivity in lectin blotting by use of *Maackia amurensis* agglutinin, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell.

[1.2.1]

The above-described Factor C, which exhibits a residual activity of 10% or higher in the presence of 21 mM sodium citrate.

[1.2.2]

The above-described Factor C, which exhibits a residual activity of 20% or higher in the presence of 21 mM sodium citrate.

[1.2.3]

The above-described Factor C, which exhibits a residual activity of 25% or higher in the presence of 52 mM sodium hydrogencarbonate.

[1.2.4]

The above-described Factor C, which exhibits a residual activity of 35% or higher in the presence of 52 mM sodium

hydrogencarbonate.

[1.2.5]

The above-described Factor C, which exhibits a residual activity of 25% or higher in the presence of 214 mM sodium chloride.

[1.2.6]

The above-described Factor C, which exhibits a residual activity of 35% or higher in the presence of 214 mM sodium chloride.

[1.2.7]

The above-described Factor C, which exhibits a residual activity of 15% or higher in the presence of 16 mM magnesium sulfate.

[1.2.8]

The above-described Factor C, which exhibits a residual activity of 25% or higher in the presence of 16 mM magnesium sulfate.

[1.2.9]

The above-described Factor C, which exhibits a residual activity of 35% or higher in the presence of 2.5 mM calcium chloride.

[1.2.10]

The above-described Factor C, which exhibits a residual activity of 45% or higher in the presence of 2.5 mM calcium chloride.

[1.2.11]

The above-described Factor C, which exhibits a higher

residual activity in the presence of 21 mM sodium citrate, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[1.2.12]

The above-described Factor C, which exhibits a higher residual activity in the presence of 52 mM sodium hydrogencarbonate, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[1.2.13]

The above-described Factor C, which exhibits a higher residual activity in the presence of 214 mM sodium chloride, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[1.2.14]

The above-described Factor C, which exhibits a higher residual activity in the presence of 16 mM magnesium sulfate, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[1.2.15]

The above-described Factor C, which exhibits a higher residual activity in the presence of 2.5 mM calcium chloride, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[1.3.1]

The Factor C, which is a protein shown in the following (A), (B), (C), or (D):

(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, and having activity of Factor C;

(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, and having activity of Factor C.

[1.3.2]

The Factor C, which is a protein shown in the following (A) or (B):

(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, and having activity of Factor C.

[1.4]

The above-described Factor C, which is a recombinant protein.

[1.5.1]

The above-described Factor C, which has a molecular weight of 115 kDa to 140 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.2]

The above-described Factor C, which has a molecular weight of 115 kDa to 130 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.3]

The above-described Factor C, which has a molecular weight of 120 kDa to 130 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.4]

The above-described Factor C, which has a molecular weight of 120 kDa to 128 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.5]

The above-described Factor C, which has a molecular weight of 127 kDa $\pm$ 5 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.6]

The above-described Factor C, which has a molecular weight of 128 kDa $\pm$ 2 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.7]

The above-described Factor C, which has a molecular weight of 127 kDa $\pm$ 2 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.5.8]

The above-described Factor C, which has a molecular weight of 126 kDa $\pm$ 2 kDa, as measured through SDS-PAGE under

a non-reducing condition.

[1.5.9]

The above-described Factor C, which has a molecular weight of 127 kDa $\pm$ 1 kDa, as measured through SDS-PAGE under a non-reducing condition.

[1.6]

The above-described Factor C, which is water-soluble.

[1.7]

The above-described Factor C, which is a culture supernatant containing Factor C.

[1.8]

The above-described Factor C, which has the following characteristics (1) to (3):

(1) having activity of Factor C;

(2) having a molecular weight of 115 kDa to 130 kDa, as measured through SDS-PAGE under a non-reducing condition; and

(3) exhibiting a residual activity of 10% or higher in the presence of 21 mM sodium citrate.

[2]

A method for producing a horseshoe crab Factor C, the method comprising expressing the horseshoe crab Factor C in a mammalian cell as a host cell.

[2.1.1]

The above-described method, wherein the mammalian cell is a mammalian cell other than COS-1.

[2.1.2]

The above-described method, wherein the mammalian cell

is a cell of a mammal selected from the group consisting of a primate and a rodent.

[2.1.3]

The above-described method, wherein the mammalian cell is a primate cell.

[2.1.4]

The above-described method, wherein the mammalian cell is a rodent cell.

[2.1.5]

The above-described method, wherein the mammalian cell is a cell of a mammal selected from the group consisting of a primate and a rodent, other than monkey.

[2.1.6]

The above-described method, wherein the mammalian cell is a Chinese hamster cell or a human cell.

[2.1.7]

The above-described method, wherein the mammalian cell is a Chinese hamster cell.

[2.1.8]

The above-described method, wherein the mammalian cell is a human cell.

[2.1.9]

The above-described method, wherein the mammalian cell is CHO or HEK.

[2.1.10]

The above-described method, wherein the mammalian cell is CHO.

[2.1.11]

The above-described method, wherein the mammalian cell is HEK.

[2.1.12]

The above-described method, wherein the mammalian cell is CHO DG44 or HEK293.

[2.1.13]

The above-described method, wherein the mammalian cell is CHO DG44.

[2.1.14]

The above-described method, wherein the mammalian cell is HEK293.

[2.2.1]

The above-described method, wherein the Factor C is a protein shown in the following (A), (B), (C), or (D):

(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, and having activity of Factor C;

(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, and having activity of Factor C.

[2.2.2]

The above-described method, wherein the Factor C is a protein shown in the following (A) or (B):

(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, and having activity of Factor C.

[3]

A horseshoe crab Factor C producible by the above-described method.

[3.1]

The above-described Factor C, which has activity of Factor C.

[3.2.1]

The above-described Factor C, which contains sialic acid.

[3.2.2]

The above-described Factor C, which contains (α -2,3) linked terminal sialic acid.

[3.2.3]

The above-described Factor C, which contains (α -2,3) linked terminal sialic acid in a greater amount, as compared with a native Factor C.

[3.2.4]

The above-described Factor C, which contains (α -2,3)

linked terminal sialic acid in a greater amount, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell.

[3.2.5]

The above-described Factor C, which exhibits a higher reactivity in lectin blotting by use of *Maackia amurensis* agglutinin, as compared with a native Factor C.

[3.2.6]

The above-described Factor C, which exhibits a higher reactivity in lectin blotting by use of *Maackia amurensis* agglutinin, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell.

[3.3.1]

The above-described Factor C, which exhibits a residual activity of 10% or higher in the presence of 21 mM sodium citrate.

[3.3.2]

The above-described Factor C, which exhibits a residual activity of 20% or higher in the presence of 21 mM sodium citrate.

[3.3.3]

The above-described Factor C, which exhibits a residual activity of 25% or higher in the presence of 52 mM sodium hydrogencarbonate.

[3.3.4]

The above-described Factor C, which exhibits a residual activity of 35% or higher in the presence of 52 mM sodium

hydrogencarbonate.

[3.3.5]

The above-described Factor C, which exhibits a residual activity of 25% or higher in the presence of 214 mM sodium chloride.

[3.3.6]

The above-described Factor C, which exhibits a residual activity of 35% or higher in the presence of 214 mM sodium chloride.

[3.3.7]

The above-described Factor C, which exhibits a residual activity of 15% or higher in the presence of 16 mM magnesium sulfate.

[3.3.8]

The above-described Factor C, which exhibits a residual activity of 25% or higher in the presence of 16 mM magnesium sulfate.

[3.3.9]

The above-described Factor C, which exhibits a residual activity of 35% or higher in the presence of 2.5 mM calcium chloride.

[3.3.10]

The above-described Factor C, which exhibits a residual activity of 45% or higher in the presence of 2.5 mM calcium chloride.

[3.3.11]

The above-described Factor C, which exhibits a higher

residual activity in the presence of 21 mM sodium citrate, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[3.3.12]

The above-described Factor C, which exhibits a higher residual activity in the presence of 52 mM sodium hydrogencarbonate, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[3.3.13]

The above-described Factor C, which exhibits a higher residual activity in the presence of 214 mM sodium chloride, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[3.3.14]

The above-described Factor C, which exhibits a higher residual activity in the presence of 16 mM magnesium sulfate, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[3.3.15]

The above-described Factor C, which exhibits a higher residual activity in the presence of 2.5 mM calcium chloride, as compared with a horseshoe crab Factor C expressed in Sf9 as a host cell and/or a native Factor C.

[3.4]

The above-described Factor C, which is a recombinant protein.

[3.5.1]

The above-described Factor C, which has a molecular weight of 115 kDa to 140 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.2]

The above-described Factor C, which has a molecular weight of 115 kDa to 130 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.3]

The above-described Factor C, which has a molecular weight of 120 kDa to 130 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.4]

The above-described Factor C, which has a molecular weight of 120 kDa to 128 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.5]

The above-described Factor C, which has a molecular weight of 127 kDa $\pm$ 5 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.6]

The above-described Factor C, which has a molecular weight of 128 kDa $\pm$ 2 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.7]

The above-described Factor C, which has a molecular weight of 127 kDa $\pm$ 2 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.8]

The above-described Factor C, which has a molecular weight of 126 kDa $\pm$ 2 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.5.9]

The above-described Factor C, which has a molecular weight of 127 kDa $\pm$ 1 kDa, as measured through SDS-PAGE under a non-reducing condition.

[3.6]

The above-described Factor C, which is water-soluble.

[3.7]

The above-described Factor C, which is a culture supernatant containing Factor C.

[4]

An endotoxin assay agent containing the above-described Factor C.

[4.1]

The above-described assay agent, which further contains a horseshoe crab Factor B and a horseshoe crab Pro-clotting enzyme.

[4.2]

The above-described assay agent, wherein the Factor B is a protein shown in the following (E) or (F) and the Pro-clotting enzyme is a protein shown in the following (G) or (H):

(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, and having activity of Factor B;

(G) a protein comprising the amino acid sequence shown in SEQ ID NO: 8;

(H) a protein comprising the amino acid sequence shown in SEQ ID NO:8 but which includes substitution, deletion, insertion, or addition of one or several amino acid residues, and having activity of Pro-clotting enzyme.

[5]

An endotoxin assay kit comprising the above-described assay agent.

[6]

A method for measuring endotoxin in a test specimen, the method comprising a step of mixing the above-described assay agent and the test specimen, and a step of measuring the progress of a cascade reaction.

[6.1.1]

The above-described method, wherein the test specimen contains an ion.

[6.1.2]

The above-described method, wherein the test specimen contains a cation.

[6.1.3]

The above-described method, wherein the test specimen contains a metal ion.

[6.1.4]

The above-described method, wherein the test specimen contains an alkali metal ion or an alkaline earth metal ion.

[6.1.5]

The above-described method, wherein the test specimen contains an alkali metal ion.

[6.1.6]

The above-described method, wherein the test specimen contains an alkaline earth metal ion.

[6.2.1]

The above-described method, wherein the test specimen contains one or more kinds of ions selected from the group consisting of sodium ion, potassium ion, calcium ion, and magnesium ion.

[6.2.2]

The above-described method, wherein the test specimen contains sodium ion.

[6.2.3]

The above-described method, wherein the test specimen contains potassium ion.

[6.2.4]

The above-described method, wherein the test specimen contains calcium ion.

[6.2.5]

The above-described method, wherein the test specimen contains magnesium ion.

[6.3.1]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 1 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.3.2]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 2 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.3.3]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 5 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.3.4]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 10 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.3.5]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 20 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.3.6]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 50 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.3.7]

The above-described method, wherein the contained amount of the ion in the test specimen is such an amount that the concentration of the cation derived from the test specimen becomes 100 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.4]

The above-described method, wherein the test specimen is an injection.

[6.5.1]

The above-described method, wherein the test specimen contains one or more kinds of salts selected from the group

consisting of sodium chloride, magnesium sulfate, sodium hydrogencarbonate, sodium citrate, calcium chloride, potassium chloride, sodium iothalamate, calcium disodium edetate, and dihydrogen sodium phosphate.

[6.5.2]

The above-described method, wherein the test specimen contains sodium chloride.

[6.5.3]

The above-described method, wherein the test specimen contains magnesium sulfate.

[6.5.4]

The above-described method, wherein the test specimen contains sodium hydrogencarbonate.

[6.5.5]

The above-described method, wherein the test specimen contains sodium citrate.

[6.5.6]

The above-described method, wherein the test specimen contains calcium chloride.

[6.5.7]

The above-described method, wherein the test specimen contains potassium chloride.

[6.5.8]

The above-described method, wherein the test specimen contains sodium iothalamate.

[6.5.9]

The above-described method, wherein the test specimen

contains calcium disodium edetate.

[6.5.10]

The above-described method, wherein the test specimen contains dihydrogen sodium phosphate.

[6.6.1]

The above-described method, wherein the contained amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 1 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.6.2]

The above-described method, wherein the contained amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 2 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.6.3]

The above-described method, wherein the contained amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 5 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.6.4]

The above-described method, wherein the contained

amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 10 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.6.5]

The above-described method, wherein the contained amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 20 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.6.6]

The above-described method, wherein the contained amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 50 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.6.7]

The above-described method, wherein the contained amount of the salt in the test specimen is such an amount that the concentration of the salt derived from the test specimen becomes 100 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the assay agent.

[6.7]

The above-described method, which further comprises a step of adding, to the reaction system, a substrate for detecting the progress of the cascade reaction.

[6.8]

The above-described method, which further comprises a step of calculating the amount of endotoxin in the test specimen.

Brief Description of the Drawings

[0018]

[Fig. 1] A chart showing a cascade reaction system of the limulus test.

[Fig. 2] A photograph showing the results of western blotting of four types of Factor C (Sf9, CHO, HEK, and TAL) derived from Japanese horseshoe crab (*Tachypleus tridentatus*), under non-reducing conditions.

[Fig. 3] A photograph (SDS-PAGE) showing the molecular weight of each of a native Factor C (TAL) derived from Japanese horseshoe crab (*Tachypleus tridentatus*) and a recombinant Factor C (CHO).

[Fig. 4] A scheme of measuring the activity of Factor C.

[Fig. 5] A chart showing a reconstituted cascade reaction system.

[Fig. 6] A table and a graph showing the activity of the four types of Factor C (Sf9, CHO, HEK, and TAL) derived from Japanese horseshoe crab (*Tachypleus tridentatus*).

[Fig. 7] A table and a graph showing the activity

inhibition by injections of the four types of Factor C (Sf9, CHO, HEK, and TAL) derived from Japanese horseshoe crab (*Tachypleus tridentatus*).

[Fig. 8] Alignment of Factor C of *Tachypleus tridentatus* (TtFC) and Factor C of *Carcinoscorpius rotundicauda* (834CrID4) (continued to Fig. 9). Consensus sequences which can undergo N-type sugar chain (N-linked sugar chain) modification are underlined.

[Fig. 9] Alignment of Factor C of *Tachypleus tridentatus* (TtFC) and Factor C of *Carcinoscorpius rotundicauda* (834CrID4) (continued from Fig. 8). Consensus sequences which can undergo N-type sugar chain (N-linked sugar chain) modification are underlined.

[Fig. 10] A schematic representation of reaction sites between Factor C and specific antibodies under reducing and non-reducing conditions.

[Fig. 11] A photograph (SDS-PAGE) showing the molecular weight of the four types of purified Factor C derived from Japanese horseshoe crab (*Tachypleus tridentatus*).

[Fig. 12] A photograph (western blotting) showing the molecular weight of the four types of purified Factor C derived from Japanese horseshoe crab (*Tachypleus tridentatus*).

[Fig. 13] A photograph (western blotting) showing the results of removal of N-type sugar chain, by glycopeptidase F, from the four types of purified Factor C derived from Japanese horseshoe crab (*Tachypleus tridentatus*).

[Fig. 14] (a) A photograph (lectin blotting) showing

the results of detection of N-type sugar chain of the four types of purified Factor C derived from Japanese horseshoe crab (*Tachypleus tridentatus*); (b) a table showing the binding specificity of lectin; and (c) a schematic representation of N-type sugar chain structures of a recombinant Factor C, assumed by the experimental results and reports by documents.

Modes for Carrying Out the Invention

[0019]

(1) Factor C of the present invention

The Factor C of the present invention is a Factor C derived from a horseshoe crab. The Factor C of the present invention is a recombinant protein. The term "recombinant protein" refers to a protein obtained through introduction of a gene encoding the protein into a host cell and heterologous expression of the gene. The Factor C of the present invention has activity of Factor C.

[0020]

Examples of the horseshoe crab include *Tachypleus tridentatus* (Japanese horseshoe crab), *Limulus polyphemus* (American horseshoe crab), *Carcinoscorpius rotundicauda* (Southeast Asian (Singaporean) horseshoe crab), and *Tachypleus gigas* (Southeast Asian horseshoe crab). Among them, *Tachypleus tridentatus* (Japanese horseshoe crab) and *Carcinoscorpius rotundicauda* (Southeast Asian (Singaporean) horseshoe crab) are preferred as a Factor C source. Furthermore, among them, *Tachypleus tridentatus* (Japanese

horseshoe crab) is more preferred as a Factor C source. The amino acid sequence of the Factor C derived from *Tachypleus tridentatus* is shown in SEQ ID NO: 2. The nucleotide sequence of a gene encoding the Factor C derived from *Tachypleus tridentatus* is shown in SEQ ID NO: 1. The amino acid sequence of the Factor C derived from *Carcinoscorpius rotundicauda* is shown in SEQ ID NO: 4. The nucleotide sequence of a gene encoding the Factor C derived from *Carcinoscorpius rotundicauda* is shown in SEQ ID NO: 3.

[0021]

The Factor C of the present invention may undergo N-type sugar chain (N-linked sugar chain) modification. The term "N-type sugar chain" refers to a sugar chain which is linked to an asparagine residue of a protein. In the Factor C derived from *Tachypleus tridentatus* and the Factor C derived from *Carcinoscorpius rotundicauda*, the amino acid residues which can undergo N-type sugar chain modification are conserved. Figs. 8 and 9 show alignments and consensus sequences (Asn-Xaa-Ser/Thr, wherein Xaa represents any amino acid residue) which can undergo N-type sugar chain modification of both types of Factor C. Thus, in particular, the Factor C derived from *Carcinoscorpius rotundicauda* is thought to be a suitable Factor C as with the Factor C derived from *Tachypleus tridentatus*.

[0022]

The Factor C of the present invention may contain a sialic acid. Examples of the sialic acid include N-

acetylneuramic acid (Neu5Ac) and N-glycolylneuramic acid (Neu5Gc). The expression "containing a sialic acid" refers to the state that a sialic acid is linked to the Factor C of the present invention. The sialic acid may be linked to Factor C directly or indirectly. In one case, a sugar chain containing a sialic acid may be linked to Factor C, whereby the sialic acid may be indirectly linked to Factor C. The sialic acid may be, for example, an (α -2,3)-linked sialic acid, more specifically, an (α -2,3)-linked terminal sialic acid. The term "(α -2,3)-linked sialic acid" refers to a sialic acid linked to a sugar via (α -2,3) glycoside linkage. The term "(α -2,3)-linked terminal sialic acid" refers to a sialic acid which is linked to a sugar via (α -2,3) glycoside linkage and which is located at a terminus of the sugar chain. An example of the sugar chain is an N-type sugar chain (N-linked sugar chain). The sialic acid may be added to Factor C through, for example, expression of Factor C in a host cell which can add a sialic-acid-containing sugar chain to a protein through modification after translation. Examples of such a host cell include mammalian cells. Sialic acid may be detected through, for example, sugar chain analysis. Sugar chain analysis may be carried out through a known technique. For example, sugar chain analysis can be carried out by using lectin or a sugar-chain-recognizing antibody. Specifically, for example, an (α -2,3)-linked terminal sialic acid can be specifically detected through lectin blotting using *Maackia amurensis* agglutinin (MAM).

[0023]

The Factor C of the present invention may contain sialic acid in a greater amount, as compared with a control Factor C. The expression "containing sialic acid in a greater amount, as compared with a control Factor C" refers to the state that the amount of sialic acid linked to the Factor C of the present invention is greater than the amount of sialic acid linked to the control Factor C, in terms of the amount by mole of sialic acid per molecule of Factor C. For example, the amount of sialic acid linked to the Factor C of the present invention may be 1.1 times or greater, 1.2 times or greater, 1.3 times or greater, 1.5 times or greater, 2.0 times or greater, 2.5 times or greater, or 3.0 times or greater than the amount of sialic acid linked to the control Factor C, in terms of the amount by mole of sialic acid per molecule of Factor C.

[0024]

Examples of the control Factor C include a recombinant Factor C expressed in insect cell Sf9, and a native Factor C. The expression "Factor C expressed in Sf9 as a host cell" refers to Factor C obtainable through expression of a gene encoding Factor C consisting of the same amino acid sequence as that of the Factor C of the present invention, in SF9 as a host cell. The term "native Factor C" refers to Factor C isolated and purified from a horseshoe crab lysate. The native Factor C may be Factor C isolated and purified from a lysate of a horseshoe crab from which the Factor C of the

present invention is derived. That is, specifically, for example, when the Factor C of the present invention is a recombinant Factor C of *Tachypleus tridentatus* or a variant thereof, the native Factor C may be Factor C isolated and purified from a lysate of *Tachypleus tridentatus*.

[0025]

Whether or not "the Factor C of the present invention contains sialic acid in a greater amount, as compared with a control Factor C" may be determined through comparison between the sialic acid amount of the Factor C of the present invention and that of the control Factor C. The amount of sialic acid may be determined through, for example, sugar chain analysis. Sugar chain analysis may be carried out through a known technique. For example, sugar chain analysis can be carried out by using lectin or a sugar-chain-recognizing antibody. Specifically, for example, an (α -2,3)-linked terminal sialic acid can be specifically quantitated through lectin blotting using *Maackia amurensis* agglutinin (MAM). It can be confirmed that the higher the reactivity in lectin blotting using MAM, the greater the amount of (α -2,3)-linked terminal sialic acid, and that is, the greater amount of (α -2,3)-linked terminal sialic acid the Factor C contains. In other words, the Factor C of the present invention may exhibit higher reactivity, as compared with the control Factor C, in lectin blotting using MAM. The expression "exhibit higher reactivity, as compared with the control Factor C, in lectin blotting using MAM" refers to the

state that, when the equiamount of the Factor C of the present invention and the control Factor C are subjected to lectin blotting using MAM, the detection intensity (such as the extent of coloring) of the spot attributed to the Factor C of the present invention is higher than that of the spot attributed to the control Factor C.

[0026]

The Factor C of the present invention may have no His-tag added to the C-terminus. Also, the Factor C of the present invention may have no V5-tag added to the C-terminus. Also, the Factor C of the present invention may have no peptide added to the C-terminus. Also, the Factor C of the present invention may have no peptide added to the N-terminus. Also, the Factor C of the present invention may have no peptide added to any of the N-terminus and the C-terminus.

[0027]

So long as the Factor C of the present invention has activity of Factor C, the Factor C may be a variant of any of the aforementioned horseshoe crab Factor C proteins (e.g., a protein having the amino acid sequence shown in SEQ ID NO: 2 or 4). Such a variant includes, for example, a homologue and an artificially modified product of the aforementioned Factor C. Notably, the amino acid sequence of the variant is not necessarily found in an actual horseshoe crab. That is, the Factor C "of a horseshoe crab or derived from a horseshoe crab" includes a variant of Factor C found in a horseshoe crab and having an amino acid sequence which is not found in

any horseshoe crab.

[0028]

The activity of Factor C refers to such an activity that the Factor C is activated in the presence of endotoxin to convert Factor B into activated Factor B. Whether "the Factor C of the present invention has activity of Factor C" can be confirmed, for example, by combining the Factor C of the present invention with a suitable Factor B and a suitable Pro-clotting enzyme in the presence of endotoxin, and detecting the progress of the cascade reaction. Specifically, the protein of SEQ ID NO: 6 and the protein of SEQ ID NO: 8 may be used as a suitable Factor B and a suitable Pro-clotting enzyme, respectively. The progress of the cascade reaction may be determined by use of the below-mentioned substrate for detection.

[0029]

So long as the Factor C of the present invention has activity of Factor C, the Factor C of the present invention may be a protein having the amino acid sequence of the above-mentioned Factor C such as the amino acid sequence shown in SEQ ID NO:2 or 4, but which includes substitution, deletion, insertion, or addition of one or several amino acid residues. Although 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, the term specifically refers to preferably 1 to 20, more preferably 1 to 10, still more

preferably 1 to 5, particularly preferably 1 to 3. The substitution, deletion, insertion, or addition of one or several amino acid residues is a conservative variation where the function of the protein is appropriately maintained. A typical conservative variation is conservative substitution. Conservative substitution is a variation among Phe, Trp, and Tyr, in the case where the substitution occurs at an aromatic amino acid residue; a variation among Leu, Ile, and Val, in the case where the substitution occurs at a hydrophobic amino acid residue; a variation between Gln and Asn, in the case where the substitution occurs at a polar amino acid residue; a variation among Lys, Arg, and His, in the case where the substitution occurs at a basic amino acid residue; a variation between Asp and Glu, in the case where the substitution occurs at an acidic amino acid residue; or a variation between Ser and Thr, in the case where the substitution occurs at an amino acid residue having a hydroxyl group. Specific examples of the substitution which can be recognized as conservative substitution include a substitution of Ala by Ser or Thr; a substitution of Arg by Gln, His, or Lys; a substitution of Asn by Glu, Gln, Lys, His, or Asp; a substitution of Asp by Asn, Glu, or Gln; a substitution of Cys by Ser or Ala; a substitution of Gln by Asn, Glu, Lys, His, Asp, or Arg; a substitution of Glu by Gly, Asn, Gln, Lys, or Asp; a substitution of Gly by Pro; a substitution of His by Asn, Lys, Gln, Arg, or Tyr; a substitution of Ile by Leu, Met, Val, or Phe; a substitution

of Leu by Ile, Met, Val, or Phe; a substitution of Lys by Asn, Glu, Gln, His, or Arg; a substitution of Met by Ile, Leu, Val, or Phe; a substitution of Phe by Trp, Tyr, Met, Ile, or Leu; a substitution of Ser by Thr or Ala; a substitution of Thr by Ser or Ala; a substitution of Trp by Phe or Tyr; a substitution of Tyr by His, Phe, or Trp; and a substitution of Val by Met, Ile, or Leu. The aforementioned substitution, deletion, insertion, addition, or the like of an amino acid residue(s) also encompasses naturally occurring variations such as those based on individual differences between horseshoe crabs and the strain and species of the horseshoe crabs, from which the gene is derived.

[0030]

The Factor C of the present invention may also be a protein which has a homology or identity of 80% or higher, preferably 90% or higher, more preferably 95% or higher, still more preferably 97% or higher, particularly preferably 99% or higher with respect to the entire amino acid sequence of Factor C (e.g., the entire amino acid sequence shown in SEQ ID NO: 2 or 4) and which has activity of Factor C.

[0031]

The gene encoding the Factor C of the present invention is not particularly limited, so long as the gene codes for the aforementioned Factor C of the present invention. The gene encoding the Factor C of the present invention may be a DNA encoding a protein having activity of Factor C, wherein the DNA fragment is hybridized with a probe prepared from a

known gene sequence, e.g., with the complementary sequence to the entirety or a part of the nucleotide sequence shown SEQ ID NO: 1 or 3, under stringent conditions. As used herein, the term "stringent conditions" generally refer to the conditions under which a specific hybrid is formed but a non-specific hybrid is not formed. An example of such conditions is conditions under which DNAs having a high homology, e.g., a homology of 80% or higher, preferably 90% or higher, more preferably 95% or higher, still more preferably 97% or higher, particularly preferably 99% or higher, are hybridized with each other, and DNAs having a homology lower than the above level are not hybridized with each other. Another example of the conditions is conditions generally employed in washing of southern hybridization; i.e., washing once, preferably 2 to 3 times, at temperature and salt concentration corresponding to 60°C, 1×SSC, 0.1% SDS, preferably 60°C, 0.1×SSC, 0.1% SDS, more preferably 68°C, 0.1×SSC, 0.1% SDS.

[0032]

In the gene encoding the Factor C of the present invention, any codon may be substituted by its equivalent codon. For example, the codon combination of the gene encoding the Factor C of the present invention may be modified such that the codon combination is optimized for expression in a mammalian cell. The optimization may be performed through employment of, for example, a conventional contract service. Notably, the gene encoding the Factor C of the present invention may be a variant of a DNA in which the

codon combination is optimized for expression in a mammalian cell.

[0033]

The above descriptions about the variants of genes and proteins may also be applied *mutatis mutandis* to Factor B, Pro-clotting enzyme, and gene encoding the same.

[0034]

The Factor C of the present invention may have a molecular weight of 115 kDa to 140 kDa, 115 kDa to 130 kDa, 120 kDa to 130 kDa, or 120 kDa to 128 kDa, as measured through SDS-PAGE under a non-reducing condition. Also, the Factor C of the present invention may have a molecular weight of 127 kDa ± 5 kDa, 128 kDa ± 2 kDa, 127 kDa ± 2 kDa, 126 kDa ± 2 kDa, or 127 kDa ± 1 kDa, as measured through SDS-PAGE under a non-reducing condition. Also, the Factor C of the present invention may have a molecular weight of 128 kDa or 126 kDa, as measured through SDS-PAGE under a non-reducing condition.

[0035]

The Factor C of the present invention may have low susceptibility to inhibition of activity by an ion. The expression "low susceptibility to inhibition of activity by an ion" refers to the state that the Factor C of the present invention exhibits a high residual activity in the presence of an ion, as compared with a control Factor C. Examples of the control Factor C include a recombinant Factor C expressed in insect cell Sf9 and a native Factor C. The meaning of the expression "exhibiting a high residual activity" is not

particularly limited, so long as the residual activity of the Factor C of the present invention is higher than that of the control Factor C. The expression "exhibiting a high residual activity" may refer to, for example, the state that the residual activity of the Factor C of the present invention is 1.1 times or higher, 1.2 times or higher, 1.3 times or higher, 1.5 times or higher, 2.0 times or higher, 2.5 times or higher, or 3.0 times or higher than the residual activity of the control Factor C. Specific examples of "low susceptibility to inhibition of activity by an ion" include such a property that the Factor C of the present invention exhibits a higher residual activity in the presence of 21 mM sodium citrate, as compared with the control Factor C; such a property that the Factor C of the present invention exhibits a higher residual activity in the presence of 52 mM sodium hydrogencarbonate, as compared with the control Factor C; such a property that the Factor C of the present invention exhibits a higher residual activity in the presence of 214 mM sodium chloride, as compared with the control Factor C; such a property that the Factor C of the present invention exhibits a higher residual activity in the presence of 16 mM magnesium sulfate, as compared with the control Factor C; and such a property that the Factor C of the present invention exhibits a higher residual activity in the presence of 2.5 mM calcium chloride, as compared with the control Factor C. Specific examples of "low susceptibility to inhibition of activity by an ion" further include such a property that the Factor C of the

present invention exhibits a residual activity of 10% or higher or 20% or higher in the presence of 21 mM sodium citrate, as compared with the control Factor C; such a property that the Factor C of the present invention exhibits a residual activity of 25% or higher or 35% or higher in the presence of 52 mM sodium hydrogencarbonate, as compared with the control Factor C; such a property that the Factor C of the present invention exhibits a residual activity of 25% or higher or 35% or higher in the presence of 214 mM sodium chloride, as compared with the control Factor C; such a property that the Factor C of the present invention exhibits a residual activity of 15% or higher or 25% or higher in the presence of 16 mM magnesium sulfate, as compared with the control Factor C; and such a property that the Factor C of the present invention exhibits a residual activity of 35% or higher or 45% or higher in the presence of 2.5 mM calcium chloride, as compared with the control Factor C. The Factor C of the present invention may have any one of the above properties singly or two or more of the above properties in combination. The "residual activity" is defined as a relative reactivity (%) observed for a measurement specimen (endotoxin concentration: 0.05 EU/mL) prepared by adding endotoxin to an ion-containing test specimen, with respect to the reactivity observed for another measurement specimen (endotoxin concentration: 0.05 EU/mL) prepared by adding endotoxin to injection water as 100%, in the assay system shown in Fig. 4.

[0036]

The Factor C of the present invention may be water-soluble. As used herein, the term "water-soluble" refers to the state that, when the Factor C of the present invention is expressed in an appropriate host cell, the thus-expressed Factor C is detected in a soluble fraction. The expression "detected in a soluble fraction" may refer to the state that 20% or more, 50% or more, 80% or more, 90% or more, or 95% or more of the expressed Factor C is detected in a soluble fraction.

[0037]

(2) Method for producing the Factor C of the present invention

The Factor C of the present invention may be produced through, for example, expression in a mammalian cell as a host. That is, the present invention provides a method for producing a horseshoe crab Factor C, the method comprising expressing the horseshoe crab Factor C in a mammalian cell as a host cell. This method may also be referred to as "the production method of the present invention." The Factor C producible through production method of the present invention is an embodiment of the Factor C of the present invention.

[0038]

The mammalian cell is not particularly limited, so long as the cell can functionally express a horseshoe crab Factor C. The term "functional expression" refers to the state that the expressed Factor C exhibits activity of Factor C.

Specifically, the mammalian cell may be a cell other than COS-1 cell. The mammalian cell is preferably a cell of a mammal selected from the group consisting of a rodent and a primate. Examples of the rodent include, but are not particularly limited to, Chinese hamster, hamster, mouse, rat, and guinea pig. Of these, Chinese hamster is preferred. Examples of the Chinese hamster cell include Chinese hamster ovary (CHO) cell line. Examples of CHO include CHO DG44 and CHO K1. Examples of the primate include, but are not particularly limited to, human, monkey, and chimpanzee. The primate may be a primate other than monkey. Of these, human is preferred. Examples of the human cell include human embryo kidney (HEK) cell line. Examples of HEK include HEK293.

[0039]

When the mammalian cell retains a gene encoding Factor C, the cell can express Factor C. The gene encoding Factor C may be retained in the mammalian cell, such that it can be expressed under the control of a promoter which functions in the cell. In the mammalian cell, the gene encoding Factor C, for example, may be present on a vector such as a plasmid which undergoes autonomous replication outside a chromosome, or may be introduced to a chromosome. The technique of introducing the gene encoding Factor C into a mammalian cell is not particularly limited. Examples of the vector which undergoes autonomous replication outside a chromosome include pCA7 (Makoto Takeda, *et al.*, J. Virol. 79(22): 14346-54

(2005)). Alternatively, the gene encoding Factor C may be introduced to a chromosome of a mammalian cell by use of pCI-Neo Vector (product of Promega). The mammalian cell may retain one copy of, or two or more copies of the gene encoding Factor C.

[0040]

The culture conditions under which a mammalian cell is cultured are not particularly limited, so long as the mammalian cell can proliferate. Conditions generally employed in culturing mammalian cells may be employed, after appropriate modification has been performed, if needed. A culture medium which is generally employed in culturing mammalian cells may be employed as the culture medium in the invention. Specifically, an RPMI 1640 medium (product of Sigma) or a DMEM medium (product of Sigma) may be used. Culturing can be performed, for example, as static culture at 36°C to 38°C under feeding of 5% CO₂.

[0041]

Whether or not Factor C has been functionally expressed can be confirmed by measuring activity of Factor C. Expression of Factor C may also be confirmed by measuring the amount of mRNA formed via transcription of a gene encoding Factor C, or detecting Factor C through western blotting by use of an antibody.

[0042]

The expressed Factor C can be recovered as a solution containing Factor C, and can be used as a component of the

endotoxin assay agent of the present invention. The solution containing Factor C may be, for example, a culture broth, a culture supernatant, a disrupted cell extract, a mixture thereof, or the like. Factor C may be used after being purified to a desired extent, or may be used without any purification. In the present invention, even when a cell culture supernatant containing expressed Factor C is used as it is without any purification, satisfactory endotoxin assay performance can be attained. Purification of Factor C may be performed through, for example, a known protein purification technique. Examples of such a technique include ammonium sulfate precipitation, gel filtration chromatography, ion exchange chromatography, hydrophobic interaction chromatography, hydroxyapatite chromatography, and so forth. In the case where a tag such as His-tag has been added to Factor C, the Factor C may be purified through affinity chromatography based on affinity to the tag. A solution containing Factor C may be used after being filtered by means of a filter. For example, a 0.22- μm filter can be used as the filter.

[0043]

(3) Endotoxin assay agent of the present invention

The Factor C of the present invention may be used in endotoxin assay. That is, the present invention provides an endotoxin assay agent containing the Factor C of the present invention. This endotoxin assay agent may also be referred to as an "endotoxin assay agent of the present invention."

The endotoxin assay agent of the present invention may further contain a factor or factors other than Factor C, depending on the mode of endotoxin assay.

[0044]

For example, the Factor C of the present invention may be used in combination with Factor B and Pro-clotting enzyme, for endotoxin assay. In other words, an embodiment of the endotoxin assay agent of the present invention is an endotoxin assay agent containing the Factor C of the present invention, Factor B, and Pro-clotting enzyme. In this case, endotoxin can be measured by detecting Clotting enzyme, which is the final product of the cascade reaction. The Factor B and the Pro-clotting enzyme contained in the embodiment of the endotoxin assay agent of the present invention may also be referred to as the "Factor B of the present invention" and the "Pro-clotting enzyme of the present invention", respectively.

[0045]

Alternatively, endotoxin can be measured by detecting an intermediate stage of the cascade reaction. In this case, it is sufficient that the endotoxin assay agent of the present invention contains a factor or factors involved in from the start of the cascade reaction to the relevant intermediate stage. Specifically, for example, when endotoxin is measured by detecting the activated Factor C, which is an intermediate of the cascade reaction, it is sufficient that the endotoxin assay agent of the present

invention contains Factor C.

[0046]

The Factor B of the present invention is a Factor B derived from a horseshoe crab. The Pro-clotting enzyme of the present invention is a Pro-clotting enzyme derived from a horseshoe crab. Examples of the horseshoe crab include *Tachypleus tridentatus* (Japanese horseshoe crab), *Limulus polyphemus* (American horseshoe crab), *Carcinoscorpius rotundicauda* (Southeast Asian (Singaporean) horseshoe crab), and *Tachypleus gigas* (Southeast Asian horseshoe crab). Among them, *Tachypleus tridentatus* (Japanese horseshoe crab) is preferred as a source of Factor B and Pro-clotting enzyme.

[0047]

The amino acid sequence of the Factor B of *Tachypleus tridentatus* and that of the Pro-clotting enzyme of *Tachypleus tridentatus* are shown in SEQ ID NOs: 6 and 8, respectively. The nucleotide sequence of a gene encoding the Factor B of *Tachypleus tridentatus* and that of a gene encoding the Pro-clotting enzyme of *Tachypleus tridentatus* are shown in SEQ ID NOs: 5 and 7, respectively.

[0048]

The Factor B of the present invention may be a variant of any of the aforementioned horseshoe crab Factor B proteins (e.g., a protein having the amino acid sequence shown in SEQ ID NO: 6), so long as the variant has activity of Factor B. Such a variant includes, for example, a homologue and an artificially modified product of the aforementioned Factor B.

The gene encoding the Factor B of the present invention is not particularly limited, so long as the gene codes for the Factor B of the present invention. The above descriptions about the variants of Factor C and the gene encoding Factor C may also be applied *mutatis mutandis* to the variants of Factor B and the gene encoding Factor B.

[0049]

The activity of Factor B refers to such an activity that the Factor B is activated in the presence of activated Factor C to convert Pro-clotting enzyme into the activated form thereof, i.e. the corresponding Clotting enzyme. Whether "the Factor B of the present invention has activity of Factor B" can be confirmed, for example, by combining the Factor B of the present invention with a suitable Factor C and a suitable Pro-clotting enzyme in the presence of endotoxin, and detecting the progress of the cascade reaction. Specifically, the protein of SEQ ID NO: 2 and the protein of SEQ ID NO: 8 may be used as a suitable Factor C and a suitable Pro-clotting enzyme, respectively. The progress of the cascade reaction may be determined by use of the below-mentioned substrate for detection.

[0050]

The Pro-clotting enzyme of the present invention may be a variant of any of the aforementioned horseshoe crab Pro-clotting enzymes (e.g., a protein having the amino acid sequence shown in SEQ ID NO: 8), so long as the variant has activity of Pro-clotting enzyme. Such a variant includes,

for example, a homologue and an artificially modified product of the aforementioned Pro-clotting enzyme. The gene encoding the Pro-clotting enzyme of the present invention is not particularly limited, so long as the gene codes for the Pro-clotting enzyme of the present invention. The above descriptions about the variants of Factor C and the gene encoding Factor C may also be applied *mutatis mutandis* to the variants of Pro-clotting enzyme and the gene encoding Pro-clotting enzyme.

[0051]

The activity of Pro-clotting enzyme is such an activity that the Pro-clotting enzyme is converted into the activated form thereof, i.e. the corresponding Clotting enzyme, in the presence of activated Factor B, to react with the below-mentioned substrate for detection. The activity of reacting with the detection substrate refers to, for example, an activity of reacting with a coagulogen to induce coagulation, or an activity of reacting with the below-described substrate represented by X-Y-Z (wherein X represents a protection group, Y represents a peptide, and Z represents a dye linked to Y via amide bond), to thereby release dye Z (e.g., an activity of reacting with Boc-Leu-Gly-Arg-pNA, to thereby release pNA). Whether "the Pro-clotting enzyme of the present invention has the activity of Pro-clotting enzyme" can be confirmed, for example, by combining the Pro-clotting enzyme of the present invention with a suitable Factor C and a suitable Factor B in the presence of endotoxin, and detecting the progress of the

cascade reaction. Specifically, the protein of SEQ ID NO: 2 and the protein of SEQ ID NO: 6 may be used as a suitable Factor C and a suitable Factor B, respectively. The progress of the cascade reaction may be measured by use of the below-mentioned substrate for detection.

[0052]

So long as the Factor B of the present invention and the Pro-clotting enzyme of the present invention has activity of Factor B and activity of Pro-clotting enzyme, respectively, the Factor B of the present invention and/or the Pro-clotting enzyme of the present invention may have any peptide or the like added thereto. Examples of such a peptide include tag sequences such as His-tag and V5-tag. Similar to Factor C of the present invention, the Factor B of the present invention and/or the Pro-clotting enzyme of the present invention may have no His-tag added to the C-terminus; may have no V5-tag added to the C-terminus; may have no peptide added to the C-terminus; may have no peptide added to the N-terminus; or may have no peptide added to any of the N-terminus and the C-terminus.

[0053]

In the gene encoding the Factor B of the present invention and/or the gene encoding the Pro-clotting enzyme of the present invention, any codon may be substituted by its equivalent codon. For example, the codon combination of the gene encoding the Factor B of the present invention and/or the gene encoding the Pro-clotting enzyme of the present

invention may be modified such that the codon combination is optimized for expression in a host cell. An example of DNA which code for Factor B of SEQ ID NO: 6 and whose codon combination is optimized for expression in an insect cell is a DNA of SEQ ID NO: 9. Notably, the gene encoding the Factor B of the present invention and/or the gene encoding the Pro-clotting enzyme of the present invention may be a variant of a DNA in which the codon combination is optimized for expression in a host cell.

[0054]

The Factor B of the present invention and the Pro-clotting enzyme of the present invention may each be a native protein or a recombinant protein.

[0055]

A native Factor B and a native Pro-clotting enzyme may each be obtained from the hematocyte extract of the aforementioned various horseshoe crabs. These factors may be used after being purified to a desired extent. Purification may be performed through, for example, a known technique (Nakamura T. *et al.*, J. Biochem. 1986 Mar; 99(3): 847-57).

[0056]

The recombinant Factor B and the recombinant Pro-clotting enzyme may each be obtained through expression in a host cell. The host cell is not particularly limited, so long as a factor of interest can be expressed. For example, a host cell generally employed for heterologous protein expression may be used. Examples of the host cell include

insect cells, animal cells, plant cells, yeast cells, and bacterial cells. Among them, an eukaryotic cell is preferred from the viewpoint of modification after translation. Specifically, an insect cell and an animal cell are more preferred.

[0057]

Examples of the animal cells include mammalian cells. In the case where an animal cell such as a mammalian cell is used, the above descriptions about production of the Factor C of the present invention may also be applied *mutatis mutandis* to production of the Factor B and the Pro-clotting enzyme.

[0058]

Examples of the insect cells include Sf9, Sf21, SF+, and High-Five. Of these, Sf9 is preferred as the insect cell.

[0059]

The technique for expressing a factor of interest in an insect cell as a host is not particularly limited, so long as the factor can be expressed. For example, techniques generally employed for heterologous protein expression may be suitably used. For example, a factor of interest can be expressed by infecting an insect cell with a virus into which a gene encoding the factor has been incorporated (the technique being called a "virus method"). Also, for example, a factor of interest can be expressed by incorporating into an insect cell a vector into which a gene encoding the factor has been incorporated, to thereby incorporate the gene into a chromosome of the host cell (the technique being called a

"stably expressing cell line method").

[0060]

<Virus method>

The virus employed in the virus method is not particularly limited, so long as an insect cell can be infected with the virus, to thereby express a factor of interest. A virus generally employed for protein expression in insect cells may be suitably used. Examples of such viruses include Baculovirus. Baculovirus is preferably Nucleopolyhedrovirus (NPV). Examples of NPV include *Autographa californica* NPV (AcNPV) and *Bombyx mori* NPV (BmNPV). NPV is preferably AcNPV.

[0061]

Incorporation of a nucleic acid into a virus may be performed through a conventional method. For example, incorporation of a nucleic acid into a virus may be performed through homologous recombination by use of a transfer vector. Examples of the transfer vector include pPSC8 (product of Protein Sciences), pFastBac (product of Life technologies corporation), and pVL1393 (product of Pharmingen). Among them, pPSC8 is a preferable transfer vector.

[0062]

An insect cell can be infected, through a conventional technique, with the virus into which a gene encoding a factor of interest has been incorporated, to thereby obtain the insect cell which retain the virus and express the factor.

[0063]

<Stably expressing cell line method>

Through incorporation of a gene encoding a factor of interest into a chromosome of an insect cell, a stably expressing cell line which stably expresses the factor can be established. The method of establishing the stably expressing cell line is not particularly limited, and a conventional technique may be employed. For example, a stably expressing cell line can be established by use of pIZ-V5 (product of Life Technologies Corporation), according to a user's instruction attached thereto.

[0064]

The conditions under which an insect cell is cultured are not particularly limited, so long as the insect cell can proliferate. Conditions generally employed in culturing insect cells may be employed, after appropriate modification has been performed, if needed. A culture medium which is generally employed in culturing insect cells may be employed as the culture medium in the invention. Examples of such a culture medium include a commercially available serum-free medium for culturing insect cells. Specifically, an Sf900III serum-free medium (product of Life Technologies Corporation) or the like may be suitably used. Culturing can be performed, for example, as shaking culture at 27°C to 28°C.

[0065]

Whether or not a factor of interest has been expressed can be confirmed by measuring activity of the factor. Expression of a factor of interest may also be confirmed by

measuring the amount of mRNA formed via transcription of a gene encoding the factor, or detecting the factor through western blotting by use of an antibody.

[0066]

The expressed factor can be recovered as a solution containing the factor, and can be used as a component of the endotoxin assay agent of the present invention. The solution containing the factor may be, for example, a culture broth, a culture supernatant, a disrupted cell extract, a mixture thereof, or the like. The factor may be used after being purified to a desired extent, or may be used without any purification. In the present invention, even when a cell culture supernatant containing the expressed factor is used as it is without any purification, satisfactory endotoxin assay performance can be attained. Purification of the factor may be performed through, for example, a known protein purification technique. Examples of such a technique include ammonium sulfate precipitation, gel filtration chromatography, ion exchange chromatography, hydrophobic interaction chromatography, hydroxyapatite chromatography, and so forth. In the case where a tag such as His-tag has been added to the factor, the factor may be purified through affinity chromatography based on affinity to the tag. A solution containing the factor may be used after being filtered by means of a filter. For example, a 0.22- μ m filter can be used as the filter.

[0067]

In the case each factor is produced through the virus method, the virus is preferably removed. The method of removing virus is not particularly limited, and a conventional technique may be employed. For example, the virus may be removed by means of a hollow fiber filtration membrane having a pore size of 500 kDa.

[0068]

In the present invention, the Factor C of the present invention, the Factor B of the present invention, and the Pro-clotting enzyme of the present invention may be separately expressed in individually established expression cells.

[0069]

The endotoxin assay agent of the present invention may contain, for example, only the Factor C of the present invention. Alternatively, the agent may contain, for example, only the Factor C of the present invention, the Factor B of the present invention, and the Pro-clotting enzyme of the present invention.

[0070]

The endotoxin assay agent of the present invention may further contain a substrate for detecting the progress of the cascade reaction. As used herein, such a substrate may be referred to as a detection substrate.

[0071]

Examples of the detection substrate include coagulogen. Coagulogen is a detection substrate with respect to Clotting

enzyme, which is the final product of the cascade reaction. When coagulogen comes into contact with Clotting enzyme, a coagulated product, coagulin, is formed. The progress of the coagulation reaction can be determined by measuring the turbidity of the reaction mixture. Coagulogen can be recovered from a hematocyte extract of a horseshoe crab (i.e., lysate). Since the nucleotide sequence of the gene encoding coagulogen has been determined (Miyata *et al*, Protein Nucleic acid Enzyme, extra issue, No. 29; p. 30-43; 1986), coagulogen can also be produced genetically according to a conventional technique.

[0072]

The detection substrate may be a synthetic substrate. The synthetic substrate is not particularly limited, so long as it has a property suitable for detection of the cascade reaction. Examples of the "property suitable for detection of the cascade reaction" include a property for detecting the presence of Clotting enzyme and a property for detecting an intermediate stage of the cascade reaction. Examples of the "property for detecting the presence of Clotting enzyme" include a property of coloring by catalytic reaction with the Clotting enzyme and a property of generating fluorescence by catalytic reaction with the Clotting enzyme. Examples of the "property for detecting an intermediate stage of the cascade reaction" include a property of coloring by catalytic reaction of a cascade reaction intermediate such as activated Factor C and a property of generating fluorescence by

catalytic reaction of a cascade reaction intermediate such as activated Factor C. Examples of the synthetic substrate include a substrate represented by formula X-Y-Z (wherein X represents a protection group, Y represents a peptide, and Z represents a dye linked to Y via amide bond). When endotoxin is present in the reaction system, an amide linkage Y-Z is cleaved by the catalytic reaction of Clotting enzyme or an intermediate, which is yielded by the cascade reaction, to release the dye Z, whereby coloring occurs or fluorescence is generated. The protective group X is not particularly limited, and a known protective group for peptide may be suitably used. Examples of such a protective group include a t-butoxycarbonyl group and a benzoyl group. The dye Z is not particularly limited, and it may be a dye detectable under visible light or may be a fluorescent dye. Examples of the dye Z include p-nitroaniline (pNA), 7-methoxycoumarin-4-acetic acid (MCA), 2,4-dinitroaniline (DNP), and Dansyl dyes. Examples of the peptide Y include Leu-Gly-Arg (LGR), Ile-Glu-Gly-Arg (IEGR) (SEQ ID NO: 10), Val-Pro-Arg (VPR), and Asp-Pro-Arg (DPR). A synthetic substrate which reacts with the Clotting enzyme or the intermediate may be appropriately selected as the synthetic substrate in accordance with the mode of endotoxin assay. For example, from the viewpoint of substrate specificity, a substrate comprising LGR as peptide Y can be suitably used for detecting the Clotting enzyme, and a substrate comprising VPR or DPR as peptide Y can be suitably used for detecting activated Factor C. The released

dye Z may be determined through a technique in accordance with the property of the target dye.

[0073]

The endotoxin assay agent of the present invention may further contain an additional component other than the relevant factors and a detection substrate, so long as the assay agent can be used for endotoxin assay. The additional component is not particularly limited, and it may be selected in consideration of storage stability, handling easiness, stability of the factors and detection substrate, and so forth.

[0074]

The endotoxin assay agent of the present invention may be formulated into any preparation such as solid, liquid, or gel. In the formulation process, additives such as an excipient, a binder, a disintegrant, a lubricant, a flavor/corrigent, a diluent, and a solvent, which are generally used in formulation, may be used. The endotoxin assay agent of the present invention as is may be used for endotoxin assay. Alternatively, the assay agent may be used for endotoxin assay after being diluted with or dispersed or dissolved in water, physiological saline, buffer, etc. Needless to say, the endotoxin assay agent of the present invention also encompasses such diluted, dispersed, dissolved, or similarly processed form of the agent.

[0075]

In the endotoxin assay agent of the present invention,

the factors and other components may be present as a mixture or present separately. For example, the factors may be mixed at any proportions in formulation, or individual factors may be formulated separately.

[0076]

The concentrations of the factors and other components contained in the endotoxin assay agent of the present invention are not particularly limited. However, each concentration is preferably adjusted so as to fall within the below-mentioned suitable concentration range for assaying endotoxin. The concentration of each factor in the endotoxin assay agent of the present invention (as a solution prepared before contact with a test specimen) may be, for example, 5 to 200 µg/mL, and is preferably 20 to 100 µg/mL, more preferably 40 to 80 µg/mL, particularly preferably about 60 µg/mL. Also, the concentration of each factor in the endotoxin assay agent of the present invention may be adjusted in accordance with the method of producing the factor. When Factor C is produced with a rodent cell as a host, the concentration of Factor C in the endotoxin assay agent of the present invention (as a solution prepared before contact with a test specimen) can also be, for example, 5 to 200 µg/mL, 10 to 50 µg/mL, or 15 to 40 µg/mL. When Factor C is produced with a primate cell as a host, the concentration of Factor C in the endotoxin assay agent of the present invention (as a solution prepared before contact with a test specimen) can also be, for example, 5 to 200 µg/mL, 50 to 150

µg/mL, or 80 to 120 µg/mL. The above-exemplified concentrations may be calculated, for example, on the assumption that all the protein species present in the filtrate of a culture supernatant which has been obtained through expression of a factor of interest via the above-exemplified technique consists of the factor of interest.

[0077]

The endotoxin assay agent of the present invention may be provided as an endotoxin assay kit. The endotoxin assay kit is not particularly limited, so long as the kit comprises the endotoxin assay agent of the present invention. The endotoxin assay kit may further comprise, for example, one or more elements selected from an endotoxin standard, a reaction container (e.g., a tube or a microplate), an instruction, and the like.

[0078]

(4) Endotoxin assay method of the present invention

When a test specimen contains endotoxin, the cascade reaction proceeds by mixing the endotoxin assay agent of the present invention with the test specimen. Through measuring the progress of the cascade reaction, endotoxin contained in the test specimen can be measured. That is, the present invention provides a method for measuring endotoxin present in a test specimen, the method comprising a step of mixing the endotoxin assay agent of the present invention and the test specimen, and a step of measuring the progress of a cascade reaction. The method is also referred to as the

"endotoxin assay method of the present invention."

[0079]

In an embodiment of the endotoxin assay method of the present invention (hereinafter may be referred to as the "first embodiment"), all the factors are mixed with the test specimen. In the first embodiment, the factors contained the endotoxin assay agent of the present invention may be contained in the reaction system from the start of the step of mixing the endotoxin assay agent of the present invention with the test specimen, or may be successively added to the reaction system.

[0080]

For example, the step of mixing the endotoxin assay agent of the present invention with the test specimen 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 Pro-clotting enzyme to the reaction system.

[0081]

The steps (A) to (C) may be performed separately, partially simultaneously, or totally simultaneously. The steps (A) to (C) may be performed in any order. For example, the step (B) may be performed after the step (A), and the step (C) may be performed after the step (B).

[0082]

In the first embodiment, the progress of the cascade reaction can be measured by adding a detection substrate to the reaction system and measuring the response (coloring, coagulation, etc.) of the substrate. The detection substrate may be contained in the reaction system from the start of the step of mixing the endotoxin assay agent of the present invention with the test specimen, or may be added to the reaction system during the progress of the step or after completion of the step. Needless to say, the first embodiment also encompasses an endotoxin assay method employing the endotoxin assay agent of the present invention which contains a detection substrate in advance.

[0083]

In the endotoxin assay method of the present invention, so long as the cascade reaction proceeds when the test specimen contains endotoxin, the Factor B and the Pro-clotting enzyme of the present invention *per se* are not need to be in contact with the test specimen. That is, another embodiment of the endotoxin assay method of the present invention (hereinafter may be referred to as a "second embodiment") is a method for measuring endotoxin present in a test specimen, the method comprising the following steps (A) to (D):

(A) a step of mixing the Factor C of the present invention with the test specimen;

(B) a step of mixing the Factor B of the present

invention with the Factor C after mixing of step (A);

(C) a step of mixing the Pro-clotting enzyme of the present invention with the Factor B after mixing of step (B); and

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

[0084]

In the second embodiment, the steps (A) to (D) may be performed separately, partially simultaneously, or totally simultaneously. For example, step A may be initiated, and then the Factor B and the Pro-clotting enzyme may be added to the reaction system during the progress of the step A or after completion of step A. Also, step B may be initiated, and then the Pro-clotting enzyme may be added to the reaction system during the progress of the step B or after completion of step B. Alternatively, all three factors may be incorporated into the reaction system from the start of step A. Still alternatively, the Factor C after the contact of step A may be recovered and used in step B, or the Factor B after the contact of step B may be recovered and used in step C.

[0085]

In the second embodiment, the progress of the cascade may be measured by adding a detection substrate to the reaction system and measuring the response (coloring, coagulation, etc.) of the substrate. The detection substrate may be contained in the reaction system from the start of

step A, or may be added to the reaction system during the progress of any step or after completion of any step.

[0086]

Alternatively, endotoxin can be measured by detecting an intermediate stage of the cascade reaction. Specifically, endotoxin can be measured by detecting activated Factor C, which is an intermediate of the cascade reaction. That is, still another embodiment of the endotoxin assay method of the present invention (hereinafter may be referred to as a "third embodiment") may be a method for measuring endotoxin present in a test specimen, the method comprising a step of mixing the Factor C of the present invention with the test specimen and a step of detecting activated Factor C. In the third embodiment, the activated Factor C can be detected by adding a detection substrate to the reaction system and measuring the response (coloring, etc.) of the substrate. The detection substrate may be contained in the reaction system from the start of the step of mixing the Factor C of the present invention with a test specimen, or may be added to the reaction system during the progress of the step or after completion of the step.

[0087]

The endotoxin assay method of the present invention, so long as the cascade reaction proceeds when the test specimen contains endotoxin, may further comprise any other arbitrary step. For example, the endotoxin assay method of the present invention may comprise a step of adding a detection substrate

to the reaction system, or a step of mixing Clotting enzyme or an intermediate, which was yielded by the cascade reaction, with the detection substrate. Also, for example, the endotoxin assay method of the present invention may comprise a step of calculating the endotoxin level of the test specimen based on the reaction of the detection substrate.

[0088]

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

[0089]

In the assay method of the present invention, the concentration of each factor in the reaction mixture is not particularly limited, so long as the cascade reaction proceeds when the test specimen contains endotoxin. The concentration of each factor may be appropriately tuned in accordance with properties of the factor and so forth. For example, the concentration of each factor, as a final concentration, may be, for example, 2.5 to 100 $\mu\text{g/mL}$, and is preferably 10 to 50 $\mu\text{g/mL}$, more preferably 20 to 40 $\mu\text{g/mL}$, particularly preferably about 30 $\mu\text{g/mL}$. Also, the concentration of each factor in the reaction mixture may be adjusted in accordance with the method of producing the factor. When Factor C is produced with a rodent cell as a host, the concentration of Factor C in the reaction mixture, as a final concentration, may also be, for example, 2.5 to 100 $\mu\text{g/mL}$, 5 to 25 $\mu\text{g/mL}$, or 7.5 to 20 $\mu\text{g/mL}$. When Factor C

is produced with a primate cell as a host, the concentration of Factor C in the reaction mixture, as a final concentration, may also be, for example, 2.5 to 100 $\mu\text{g/mL}$, 25 to 75 $\mu\text{g/mL}$, or 40 to 60 $\mu\text{g/mL}$. The above-exemplified concentrations may be calculated, for example, on the assumption that all the protein species present in the filtrate of a culture supernatant which has been obtained through expression of a factor of interest via the above-exemplified technique consists of the factor of interest.

[0090]

In the assay method of the present invention, the concentration of the detection substrate in the reaction mixture is not particularly limited, so long as the cascade reaction proceeds when the test specimen contains endotoxin. The concentration of the detection substrate may be appropriately tuned in accordance with properties of the detection substrate and so forth. In the case where the detection substrate is a synthetic substrate, the concentration of the detection substrate is, for example, generally 0.001 mM to 100 mM, preferably 0.01 mM to 10 mM, as a final concentration.

[0091]

In any embodiment, so long as the cascade reaction proceeds when the test specimen contains endotoxin, the reaction system may further contain any other arbitrary component, in addition to the factors, the detection substrate, and the test specimen.

[0092]

The pH of the reaction mixture is not particularly limited, so long as the cascade reaction proceeds when the test specimen contains endotoxin. The pH of the reaction mixture may be appropriately tuned in accordance with properties of the factors. The pH of the reaction mixture is, for example, generally 5 to 10, preferably 7 to 8.5.

[0093]

The reaction temperature is not particularly limited, so long as the cascade reaction proceeds when the test specimen contains endotoxin. The reaction temperature may be appropriately tuned in accordance with properties of the factors. The reaction temperature is, for example, generally 10°C to 80°C, preferably 20°C to 50°C. For example, the reaction temperature may be 37°C.

[0094]

The reaction time is not particularly limited. The reaction time may be appropriately tuned in accordance with various conditions such as properties of the factors and reaction temperature. The reaction time is, for example, generally 5 minutes to 2 hours, preferably 15 minutes to 90 minutes. The reaction time may be, for example, 30 minutes to 40 minutes.

[0095]

In any embodiment, the test specimen, the factors, and other components may be further added singly or in any combination to the reaction system during the course of

reaction. These components may be added once or a plurality of times, or in a continuous manner. The reaction conditions may be constant from the start to the end of the reaction, or may be varied in the course of the reaction.

[0096]

The progress of the cascade reaction attributable to the presence of endotoxin can be measured by measuring the response (coloring, coagulation, etc.) of the detection substrate, whereby endotoxin in the test specimen can be measured. The response (coloring, coagulation, etc.) of the detection substrate may be measured through a technique in accordance with the property of the detection substrate employed.

[0097]

In the case of quantitatively measuring endotoxin, correlation data between endotoxin level and the extent of response (coloring, coagulation, etc.) of the detection substrate are obtained by use of an endotoxin standard sample with known concentration, and then the amount of endotoxin present in the specimen can be quantitatively determined on the basis of the obtained correlation data. The correlation data is, for example, a calibration curve. The quantitation may be carried out through a kinetic method or an end-point method.

[0098]

The test specimen which can be subjected to endotoxin assay is not particularly limited. Examples of the specimen

include water for medical use, pharmaceutical products, infusion solutions, blood products, medical apparatuses, medical instruments, cosmetics, foods and beverages, environmental specimens (e.g., air, river water, and soil), biological specimens (e.g., blood, body fluid, and tissue), native proteins, recombinant proteins, nucleic acids, and saccharides. The test specimen may be, for example, an injection. An injection refers to an agent that can be administered to the biological body via injection. Such an injection is not necessarily fluid during commercial distribution, and may be a lyophilized product. The test specimen itself, or an extract or wash liquid thereof may be mixed, dispersed, or dissolved in the reaction system, to thereby be subjected to endotoxin assay.

[0099]

As described above, the Factor C of the present invention may have low susceptibility to inhibition of activity by an ion. Thus, in an embodiment of the present invention, endotoxin present in a test specimen containing an ion can be suitably measured.

[0100]

In other words, the test specimen of the invention may be a test specimen containing an ion. The expression "containing an ion" refers to the state that the test specimen contains a substance which is present in the form of an ion during endotoxin assay. That is, "ion" referred to in the present invention may be species which are present

inherently in an ionized form in the test specimen, or may be species which are present inherently in a salt form in the test specimen but are ionized during endotoxin assay. The type of ions is not particularly limited. An example of the ion is a cation, and an example of the cation is a metal ion. Examples of the metal ion include an alkali metal ion and an alkaline earth metal ion. Specific examples of the alkali metal ion and the alkaline earth metal ion include sodium ion, potassium ion, calcium ion, and magnesium ion. The contained amount of the ion in the test specimen may be such an amount that, for example, the concentration of the cation derived from the test specimen becomes 1 mM or higher, 2 mM or higher, 5 mM or higher, 10 mM or higher, 20 mM or higher, 50 mM or higher, or 100 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the endotoxin assay agent. Specific examples of the salt include sodium chloride, magnesium sulfate, sodium hydrogencarbonate, sodium citrate, calcium chloride, potassium chloride, sodium iothalamate, calcium disodium edetate, and dihydrogen sodium phosphate. The contained amount of the salt in the test specimen may be such an amount that, for example, the concentration of the salt derived from the test specimen becomes 1 mM or higher, 2 mM or higher, 5 mM or higher, 10 mM or higher, 20 mM or higher, 50 mM or higher, or 100 mM or higher, as a final concentration in the reaction system after mixing the test specimen with the endotoxin assay agent. The test specimen may contain one kind of ion (or salt) or two or

more kinds of ions (or salts).

Examples

[0101]

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

[0102]

1. Preparation of Factor C proteins

(1) Expression of Factor C in insect cells (Sf9)

In this section, Factor C was prepared by use of insect cell Sf9 as a host in the following manner.

[0103]

A DNA encoding Factor C of Japanese horseshoe crab, *Tachypleus tridentatus*, was inserted between the *EcoRV* recognition site and the *MluI* recognition site of pIZ-V5 (product of Life Technologies Corporation), which is a vector for expression in insect cells, to thereby construct a Factor C expression plasmid. The nucleotide sequence of the DNA is shown in SEQ ID NO: 1, and the amino acid sequence of Factor C encoded by the DNA is shown in SEQ ID NO: 2 (the same applies throughout the Example).

[0104]

The Factor C expression plasmid was introduced into cultured Sf9 cells through transfection by use of Celfectin reagent (product of Life Technologies Corporation). The Sf9

cells were statically cultured at 28°C in an Sf900 III serum-free medium (product of Life Technologies Corporation) containing 300 to 600 µg/mL Zeocin (product of Life Technologies Corporation), whereby Sf9 strains into which the genome the expression plasmid had been incorporated were selected.

[0105]

Candidates for Sf9 in which the Factor C gene had been stably expressed were isolated through the cloning cylinder technique, and a plurality of Sf9 cell lines was cloned. The thus-obtained clones were individually cultured, to thereby obtain culture supernatants. Secretion of the recombinant Factor C protein in each culture supernatant was confirmed through western blotting by use of an anti-Factor C antibody (2C12 antibody; Yoshiki Miura, *et al.*, J. Biochem. 112: 476-481 (1992)). Also, activity of Factor C (property of being activated by endotoxin) in the culture supernatant was confirmed through activity measurement by use of a synthetic substrate Boc-LGR-pNA. Notably, the procedure of activity measurement is described in "4. Activity measurement" below (the same applies throughout the Example). Based on the results of western blotting and activity measurement, an Sf9 cell line highly expressing Factor C was selected.

[0106]

The Sf9 cell line highly expressing Factor C was suspension-cultured (28°C) in an Sf900 III medium containing 1× penicillin/streptomycin (product of Life Technologies

Corporation) and 50 µg/mL Zeocin to a later phase of the logarithmic growth phase (6 to 8×10^6 cells/mL). Then, the culture was centrifuged ($3,000 \times g$, 30 minutes, 4°C), to thereby recover a culture supernatant. The supernatant was filtered through a $0.22\text{-}\mu\text{m}$ filter, and the thus-recovered fraction (i.e. filtrate) was employed as recombinant Factor C (Sf9).

[0107]

(2) Expression of Factor C in mammalian cells (CHO DG44)

In this section, Factor C was prepared by use of CHO DG44, which is a Chinese hamster ovary cell line, as a host through the following procedure.

[0108]

A DNA encoding Factor C of Japanese horseshoe crab, *Tachypleus tridentatus*, was inserted between the *EcoRI* recognition site and the *XbaI* recognition site of pCI-neo (product of Promega), which is a vector for expression in mammalian cells, to thereby construct a Factor C expression plasmid. A kozak sequence (GCCACC) was added just before the start codon of Factor C.

[0109]

The Factor C expression plasmid and a dhfr expression plasmid were incorporated into cultured CHO DG44 cells through simultaneous transfection using a lipofection reagent (Lipofectamine LTX) (product of Life Technologies Corporation). The CHO DG44 cells were statically cultured at 37°C under feeding of 5% CO_2 in an RPMI 1640 medium (5%

dialyzed serum, containing 1× penicillin/streptomycin) (product of Sigma) added with 1 mg/mL Geneticin (product of Life Technologies Corporation), whereby CHO DG44 strains into which the genome the expression plasmids had been incorporated were selected.

[0110]

Fifteen days after the simultaneous transfection, MTX (methotrexate) (product of Wako Pure Chemical Industries, Ltd.) was added to the culture medium. The MTX concentration was elevated stepwise from 50 nM to 5,000 nM over three months, and CHO DG44 cell lines highly expressing Factor C were selected as polyclones. Effective amplification of the incorporated Factor C gene by virtue of MTX was confirmed by detecting Factor C in a culture supernatant through western blotting using a 2C12 antibody, and quantitating the transcriptional amount of mRNA of Factor C through real-time PCR.

[0111]

The group of polyclonal CHO DG44 cell lines highly expressing Factor C was diluted by the medium to obtain a cell concentration of 0.5 cells/well, and the dilute was inoculated to a 96-well plate. From about 10 to 20 days after inoculation, the formed cell colonies were successively subjected to expansion culture, whereby CHO DG44 cell lines highly expressing Factor C were cloned. The transcriptional amount of mRNA of Factor C was confirmed through real-time PCR. The amount of Factor C protein secreted to the medium

was confirmed through western blotting using a 2C12 antibody. The Factor C activity (property of being activated by endotoxin) in the culture supernatant was confirmed through activity measurement using a synthetic substrate Boc-LGR-pNA. Based on these results, a monoclonal CHO DG44 cell line highly expressing Factor C was selected.

[0112]

The CHO DG44 cell line highly expressing Factor C (monoclonal) was conditioned in a serum-free complete synthetic medium containing 5 μ M MTX and thus floated. The cell line was grown at 37°C under feeding of 5% CO₂ to a later phase of the logarithmic growth phase. The thus-obtained floating culture broth was centrifuged (3,000 $\times$ g, 30 minutes, 4°C), to thereby recover a culture supernatant. The supernatant was filtered through a 0.22- μ m filter, and the thus-recovered fraction (i.e. filtrate) was employed as recombinant Factor C (CHO).

[0113]

(3) Expression of Factor C in mammalian cells (HEK293)

In this section, Factor C was prepared by use of HEK293, which is a human embryo kidney cell line, as a host through the following procedure.

[0114]

A DNA encoding Factor C of a Japanese horseshoe crab, *Tachypleus tridentatus*, was inserted between the *Eco*RI recognition site and the *Xho*I recognition site of pCA7 (Makoto Takeda, *et al.*, J. Virol. 79 (22): 14346-54 (2005)),

which is a vector for expression in mammalian cells, to thereby construct a Factor C expression plasmid. A kozak sequence (GCCACC) was added just before the start codon of Factor C.

[0115]

The Factor C expression plasmid was incorporated into cultured HEK293 cells through transfection using polyethylenimine (product of Sigma) (Hashiguti *et al.*, Expression of Recombinant Protein Using Cultured Human Cells -Standard Protocol by 293-type cells-, PSSJ Archives, 1, e017 (2008), http://www.pssj.jp/archives/Protocol/Expression/293_01/293_01_01.html). HEK293 cells were statically cultured in a DMEM medium (containing 10% fetal bovine serum and 2mM L-glutamine) (product of Sigma) at 37°C under feeding of 5% CO₂ without replacement of the medium. Four days after transfection, the culture broth was recovered, and was centrifuged (3,300×g, 30 minutes, 4°C), to thereby recover a culture supernatant. The supernatant was filtered through a 0.22-μm filter, and the thus-recovered fraction (i.e. filtrate) was employed as recombinant Factor C (HEK).

[0116]

(4) Preparation of native Factor C (derived from amebocyte of *Tachypleus tridentatus*)

A fraction containing Factor B and Factor C was recovered from an amebocyte extract of Japanese horseshoe crab, *Tachypleus tridentatus*, through column chromatography

by use of dextran sulfate resin (Takanori Nakamura, *et al.*, Eur. J. Biochem. 154: 511-521 (1986)). The fraction (5 mL) was subjected to gel filtration by means of a column (ϕ 2.2 cm $\times$ 97 cm) filled with Sepharose CL6B gel (product of GE Healthcare). Gel filtration was performed under almost the same conditions as employed in a known technique (Jeak Ling Ding and Bow Ho, US 5,712,144; Jeak L. Ding, *et al.*, Biochem. Biophys. Acta 1202: 149-156). The flow rate was adjusted to 15 mL/h, and 50 mM Tris buffer (pH 8.0) containing 154 mM NaCl, 1 mM EDTA, and 5% DMSO was employed as a solvent.

[0117]

Gel filtration eluted fractions (3.7 mL/tube, 150 tubes) were subjected to SDS-PAGE followed by CBB staining and western blotting using a 2C12 antibody, and activity measurement using a synthetic substrate Boc-LGR-pNA, whereby fractions containing Factor C protein were identified. These fractions containing the purified Factor C protein were employed as native Factor C (TAL).

[0118]

2. Preparation of recombinant Factor B and recombinant Pro-clotting enzyme

A DNA encoding Factor B of Japanese horseshoe crab, *Tachypleus tridentatus*, was inserted between the *EcoRV* recognition site and the *MluI* recognition site of pIZ-V5 (product of Life Technologies Corporation), which is a vector for expression in insect cells, to thereby construct a Factor B expression plasmid. The nucleotide sequence of the DNA is

shown in SEQ ID NO: 9, and the amino acid sequence of Factor B encoded by the DNA is shown in SEQ ID NO: 6. Notably, the nucleotide sequence shown in SEQ ID NO: 9 is a nucleotide sequence optimized for expression in insect cells.

[0119]

A DNA encoding Pro-clotting enzyme of Japanese horseshoe crab, *Tachypleus tridentatus*, was inserted between the *EcoRV* recognition site and the *MluI* recognition site of pIZ-V5 (product of Life Technologies Corporation), which is a vector for expression in insect cells, to thereby construct a Pro-clotting enzyme expression plasmid. The nucleotide sequence of the DNA is shown in SEQ ID NO: 7, and the amino acid sequence of Pro-clotting enzyme encoded by the DNA is shown in SEQ ID NO: 8.

[0120]

Through the same method as employed in the case of Factor C, the expression plasmids were each incorporated into Sf9 cells, high-expression clones were selected, and culture supernatants thereof were prepared. The culture supernatants were individually filtered through a 0.22- μ m filter, and the obtained fractions (i.e. filtrates) were employed as a recombinant Factor B and a recombinant Pro-clotting enzyme. Recovery of the factors was confirmed through western blotting employing an antibody specific to each factor and activity measurement.

[0121]

3. Comparison of molecular weights of Factor C proteins (1)

The molecular weights of the above-prepared four types of Factor C proteins were compared with one another through SDS-PAGE and western blotting.

[0122]

Firstly, each Factor C in an amount shown in Fig. 2 was subjected to SDS-PAGE under a non-reducing condition employing a 5 to 20% gradient gel. In Fig. 2, Sf9, CHO, and HEK denote the Factor C expressed in Sf9 cells, CHO DG44 cells, and HEK293 cells, respectively, and TAL refers to native Factor C (hereinafter the same applies). Notably, Factor C is cleaved into an H chain and an L chain under reducing conditions. In the present Example, SDS-PAGE was carried out under a non-reducing condition in order to compare the molecular weights of Factor C in an intact state.

[0123]

After SDS-PAGE, proteins were transferred to a PVDF membrane (product of Bio RAD) by means of a semi-dry blotter. The PVDF membrane was recovered and blocked with 5% skim milk, and then sequentially treated with a primary antibody (2C12 antibody) and a secondary antibody (HRP-labeled anti-mouse goat antibody) (product of Dako). Bands attributed to Factor C were made to emit light with a detection reagent, SuperSignal West Dura (product of Thermo Scientific), and the light emission was recorded by a CCD camera.

[0124]

The four types of Factor C were found to have different molecular weights, and the molecular weight was the greatest

in the case of CHO, followed by TAL, HEK, and Sf9 in the descending order (Fig. 2).

[0125]

Regarding Singaporean horseshoe crab, *Carcinoscorpius rotundicauda*, it has been reported that all of the native Factor C protein purified from an amebocyte extract, and recombinant Factor C proteins produced in insect cells Sf9 and S2, and in African green monkey kidney cell line COS-1 as a host cell have the same molecular weight of 132 kDa (Jeak Ling Ding and Bow Ho, US 5,712,144, and Jeak L. Ding, *et al.*, Biochem. Biophys. Acta 1202: 149-156 (1993) (for native Factor C protein); Jing Wang, *et al.*, J. Biol. Chem. 277(39): 36363-72 (2002) (for Sf9 and S2); and Roopashree S. Dwarakanath, *et al.*, Biotechnology letters 19(4): 357-361 (1997) (for COS-1)).

[0126]

Thus, among the above-prepared four types of Factor C, the molecular weight of each of CHO and TAL was correctly measured. Firstly, recombinant Factor C (CHO) was purified in a manner similar to that employed in the case of native Factor C (TAL). Then, electrophoresis (15% gel, LMW Marker kit (product of GE Healthcare)) was performed under the same conditions as employed in a known technique (Jeak Ling Ding and Bow Ho, US 5,712,144; and Jeak L. Ding, *et al.*, Biochem. Biophys. Acta 1202: 149-156), and the molecular weight of each Factor C was then determined through Ferguson plotting. As a result, recombinant Factor C (CHO) was found to have a

molecular weight of 126 kDa, and native Factor C (TAL) was found to have a molecular weight of 123 kDa (Fig. 3). Thus, native Factor C (TAL) and recombinant Factor C (CHO) derived from Japanese horseshoe crab, *Tachypleus tridentatus*, were found to have a molecular weight smaller than that of the Factor C derived from Singaporean horseshoe crab, *Carcinoscorpius rotundicauda* (132 kDa).

[0127]

The difference in molecular weight among the above-prepared four types of Factor C is conceived to be attributed to the difference in post-translation modification (sugar chain modification) depending on the type of host cells employed. For example, it has been known that sialic acid is linked to the N-type sugar chain after translation in mammalian cells, whereby a recombinant protein produced in mammalian cells has dimensions larger than those of a recombinant protein produced in insect cells (Robert L. Harrison and Donald L. Jarvis, *Methods in Molecular Biology* 338: 341-356 (2007)). This supports the results of the present Example (Fig. 2).

[0128]

4. Activity measurement

Each of the above-prepared four types of Factor C was combined with other factors, and activity measurement was carried out through the following procedure. Fig. 4 shows the scheme of activity measurement.

[0129]

As shown in Fig. 4, common materials other than Factor C (a recombinant Factor B, a recombinant Pro-clotting enzyme, a synthetic substrate Boc-LGR-pNA, and Tris buffer) were mixed together, to thereby prepare a common liquid mixture. To the common liquid mixture, Factor C in an amount specified in Fig. 6 was added, and the total volume was adjusted to 50 μ L. The thus-obtained mixture was mixed with 50 μ L of a specimen (water containing United States Pharmacopoeia standard endotoxin (USP-RSE) (product of Seikagaku corporation)), and the resultant mixture was heated at 37°C for 30 minutes. In this assay system, Factor C is activated by endotoxin, to thereby form activated Factor C; Factor B is activated by the activated Factor C, to thereby form activated Factor B; Pro-clotting enzyme was activated by the activated Factor B, to thereby form a corresponding Clotting enzyme; and the Clotting enzyme cleaves a synthetic substrate Boc-LGR-pNA, whereby p-nitroaniline is released (Fig. 5). The change in absorbance (A 405 nm) attributed to formation of p-nitroaniline was measured in a time-dependent manner, and the absorbance change rate per unit time (mAbs/min) was calculated and employed as Factor C activity. The Measurement was conducted thrice for each sample.

[0130]

In the above assay system, the final concentration of each factor was as follows: recombinant Factor B 30 μ g/mL, recombinant Pro-clotting enzyme 30 μ g/mL, recombinant Factor C (Sf9) 11.3 μ g/mL, recombinant Factor C (CHO) 12 μ g/mL,

recombinant Factor C (HEK) 51.5 µg/mL, and Factor C (TAL) 0.25 µg/mL. The above-exemplified concentrations (except for the case of TAL) were calculated, on the assumption that all the protein species present in the sample (i.e. filtrate) prepared through expression of a factor of interest consisted of the factor of interest. The Factor C (TAL) concentration was measured after purification of Factor C (TAL).

[0131]

As a result, reconstituted systems each exhibiting almost equivalent activity were successfully constituted for the four types of Factor C (Fig. 6). In each reconstituted system, the activity was increased with an increase in endotoxin concentration (0.05 and 0.1 EU/mL) of a specimen.

[0132]

The recombinant Factor C derived from *Carcinoscorpius rotundicauda* and produced in mammalian cell COS-1 (132 kDa) is reported to be recovered in an insoluble fraction (Roopashree S. Dwarakanath, *et al.*, Biotechnology letters 19(4): 357-361 (1997); and Jing Wang, Bow Ho and Jeak L. Ding, Biotechnology letters 23: 71-76 (2001)). Also, the recombinant Factor C derived from *Carcinoscorpius rotundicauda* and produced in insect cell S2 (132 kDa) is reported to exhibit no protease activity in response to endotoxin (Jing Wang, *et al.*, J. Biol. Chem. 277(39): 36363-72 (2002)). Lack of activity of the latter Factor C (produced in S2) is thought to be attributed to the difference in sugar chain structure from the native Factor C

derived from *Carcinoscorpius rotundicauda* and the recombinant Factor C produced in insect cell Sf9, due to difference in reactivity to lectin.

[0133]

Meanwhile, in the present Example, it was found that the recombinant Factor C derived from *Tachyplesus tridentatus* (Sf9, CHO, and HEK) exhibited an endotoxin-dependent activity, even though the molecular weight thereof differs from that of native Factor C (TAL); i.e., even though the sugar chain structure thereof differs from that of native Factor C (TAL).

[0134]

5. Inhibition of activity by injection

Endotoxin is a strong immune reaction-inducing substance. Thus, when an injection contaminated with endotoxin is administered to the body, a grave side effect occurs. Therefore, in production of injections, detection of endotoxin by use of a limulus amebocyte lysate reagent is obligated by the pharmacopoeia of the relevant country, to thereby confirm no endotoxin contamination.

[0135]

Thus, the above-prepared four types of Factor C were compared in terms of reactivity to endotoxin in various injections.

[0136]

As a control specimen, injection water containing endotoxin (endotoxin concentration: 0.05 EU/mL) was used. Measurement specimens used were as follows: 4-fold dilute of

10 w/v% sodium chloride injection (10% sodium chloride injection, product of Otsuka Pharmaceutical Co., Ltd.); 16-fold dilute of 0.5 M magnesium sulfate injection (Mg sulfate corrective injection 1 mEq/mL, product of Otsuka Pharmaceutical Co. Ltd.); undiluted solution of physiological saline (Otsuka isotonic sodium chloride solution, product of Otsuka Pharmaceutical Co., Ltd.); 8-fold dilute of 7 w/v% sodium hydrogencarbonate injection (Meylon injection 7%, product of Otsuka Pharmaceutical Co., Ltd.); 8-fold dilute of 10 w/v% sodium citrate injection (sodium citrate injection for transfusion, product of Fuso Pharmaceutical Industries, Ltd.); 100-fold dilute of 0.5 M calcium chloride injection (Ca chloride corrective injection 1 mEq/mL, product of Otsuka Pharmaceutical Co., Ltd.); undiluted solution of Ringer's solution (Ringer's solution "Fuso", product of Fuso Pharmaceutical Industries, Ltd.); and 16-fold dilute of sodium iothalamate injection (Conray 400 injection, product of Daiichi Sankyo Co., Ltd.), each spiked with endotoxin (endotoxin concentration: 0.05 EU/mL). When the measurement specimen was 8-fold dilute of 10 w/v% sodium citrate injection, the final sodium citrate concentration was about 21 mM. When the measurement specimen was 8-fold dilute of 7 w/v% sodium hydrogencarbonate injection, the final sodium hydrogencarbonate concentration was about 52 mM. When the measurement specimen was 4-fold dilute of 10 w/v% sodium chloride injection, the final sodium chloride concentration was about 214 mM. When the measurement specimen was

undiluted solution of physiological saline, the final sodium chloride concentration was about 77 mM. When the measurement specimen was 16-fold dilute of 0.5 M magnesium sulfate injection, the final magnesium sulfate concentration was about 16 mM. When the measurement specimen was 100-fold dilute of 0.5 M calcium chloride injection, the final calcium chloride concentration was about 2.5 mM. Activity of Factor C was measured through the procedure shown in Fig. 4. A residual activity was defined as a relative reactivity (%) for endotoxin in an injection specimen, with respect to the reactivity for endotoxin in the corresponding control specimen as 100%. The measurement was carried out four times for each injection specimen.

[0137]

Fig. 7 shows the results. When a typical injection was employed as a measurement specimen, reaction with endotoxin was inhibited, as compared with the case in which injection water was used. The degree of inhibition varied in accordance with the type of injection and the type of host for expressing Factor C. Recombinant Factor C (CHO) and recombinant Factor C (HEK) showed a tendency to have low susceptibility to reaction inhibition to all the tested injections, as compared with native Factor C (TAL). Particularly, recombinant Factor C (CHO) exhibited the highest residual activity in many cases. In contrast, recombinant Factor C (Sf9) was most susceptible to reaction inhibition in many injections (7 injections except sample No.

6).

[0138]

The test results indicate that Factor C expressed in mammalian cells can have low susceptibility to activity inhibition by ions. Such a property is particularly advantageous for detection of endotoxin contamination in production of injections.

[0139]

6. Preparation of L chain-specific Factor C protein antibody

A Factor C protein is known to be present as a single chain (Full chain) under non-reducing conditions, and to be cleaved into two chains (H chain and L chain) under reducing conditions. The anti-Factor C monoclonal antibody (2C12 antibody) is reported to recognize the Full chain and the H chain (Yoshiki Miura, *et al.*, J. Biochem. 112: 476-481(1992)). Thus, a peptide antigen present in the L chain was produced. A rabbit was immunized with the peptide antigen through a conventional method, whereby a polyclonal antibody which can recognize the L chain and the Full chain (FCL antibody) was produced (Fig. 10).

[0140]

7. Purification of recombinant Factor C proteins

According to the method employed in "(4) Preparation of native Factor C (derived from *Tachypleus tridentatus*)" of "1. Preparation of Factor C proteins", three types of recombinant Factor C proteins were purified from culture supernatants of mammalian cells (CHO DG44, and HEK293) and insect cells (Sf9).

Briefly, each supernatant (100 to 300 mL) was subjected to column chromatography by use of dextran sulfate resin, and elution fractions containing the corresponding recombinant Factor C were isolated through gel filtration. Purification of the recombinant Factor C proteins was confirmed through SDS-PAGE and CBB staining, western blotting employing the 2C12 antibody, and activity measurement.

[0141]

8. Comparison of molecular weights of Factor C proteins (2)

The molecular weights of the above-purified four types of Factor C proteins were compared again with one another through SDS-PAGE and western blotting.

[0142]

The four types of purified Factor C proteins, derived from a native horseshoe crab (TAL), a culture supernatant of CHO DG44 (CHO), a culture supernatant of HEK293 (HEK), and a culture supernatant of Sf9 (Sf9), were applied to a single gel (15% gel) for SDS-PAGE, and subjected to CBB staining (Fig. 11). Each of the four types of purified Factor C proteins presented as a single chain (Full chain) under non-reducing conditions, and was cleaved into two chains (H chain and L chain) under reducing conditions. After transfer to the PVDF membrane, western blotting was performed by use of the 2C12 antibody and the FCL antibody (Fig. 12). In relation to antibody recognition sites (Fig. 10), the 2C12 antibody specifically recognized the Full chain and the H chain, and the FCL antibody specifically recognized the Full

chain and the L chain. The CBB-stained bands shown in Fig. 11 were identified to bands derived from Factor C. Regarding molecular weight of Factor C, CHO had the largest molecular weight; TAL and HEK had almost the same molecular weight; and Sf9 has the smallest molecular weight, in all cases of the Full chain under non-reducing conditions and of the H-chain and L chain under reducing conditions.

[0143]

In order to more precisely compare the molecular weights of the four types of purified Factor C, electrophoresis (15% gel, LMW marker (product of GE Healthcare)) was performed under the same conditions as employed in a known technique (Jeak Ling Ding and Bow Ho, US 5,712,144; and Jeak L. Ding, *et al.*, Biochem. Biophys. Acta 1202: 149-156), followed by CBB staining, and the molecular weights were then determined through Ferguson plotting.

[0144]

Table 1 shows the results. Under non-reducing conditions, TAL had a molecular weight of 124 kDa, which is almost equivalent to 123 kDa reported by the reference. The molecular weight of CHO was higher, 128 kDa, and that of HEK was 124 kDa, which is equivalent to that of TAL. The molecular weight of Sf9 was 109 kDa, which is smaller than that of TAL. As a result, when recombinant Factor C was expressed in insect cells (Sf9), the molecular weight thereof was found to be smaller than that of native Factor C (TAL), whereas when recombinant Factor C was expressed in mammalian

cells (CHO, HEK), the molecular weight thereof was found to be equivalent to or larger than that of native Factor C (TAL). This tendency was also confirmed in the case of the H chain or the L chain under reducing conditions.

[0145]

The molecular weight of native Factor C derived from *Carcinoscorpius rotundicauda* (Singaporean horseshoe crab) and that of recombinant Factor C thereof obtained via gene expression in insect cells have been reported to be the same value, 132 kDa, under non-reducing conditions. The four types of purified Factor C derived from *Tachypleus tridentatus* (Japanese horseshoe crab) and obtained in the present Example were found to have a molecular weight smaller than 132 kDa (Table 1).

[0146]

[Table 1]

Species of horseshoe crab	Source	Mol. wt. (kDa)			Reference
		Full	H	L	
<i>Tachypleus tridentatus</i>	Natural lysate	124	85	42	Present Example
<i>Tachypleus tridentatus</i>	CHO DG44	128	88	43	Present Example
<i>Tachypleus tridentatus</i>	HEK293	124	85	42	Present Example
<i>Tachypleus tridentatus</i>	Sf9	109	75	39	Present Example
<i>Tachypleus tridentatus</i>	Natural lysate	123	80	43	Takanori Nakamura, <i>et al.</i> , Eur. J. Biochem. 154: 511-521 (1986)
<i>Carcinoscorpius rotundicauda</i>	Natural lysate	132	80	52	Jeak L. Ding, <i>et al.</i> , Biochem. Biophys. Acta 1202: 149-156 (1993)
<i>Carcinoscorpius rotundicauda</i>	Sf9 (+baculo virus)	132	No data	No data	Jing Wang, <i>et al.</i> , J. Biol. Chem. 277 (39): 36363-72 (2002)
<i>Carcinoscorpius rotundicauda</i>	S2	132	No data	No data	Jing Wang, <i>et al.</i> , J. Biol. Chem. 277 (39): 36363-72 (2002)

[0147]

9. Confirmation of N-type sugar chain modification

The genes employed in the present Example for expressing the recombinant Factor C were sequences all derived from *Tachypleus tridentatus*, and the expression plasmids were designed so that no tag was added to any terminus of each sequence. Therefore, the translated amino acid sequences of the four types of Factor C obtained in the present Example are thought to be the same one. In addition,

the partial sequences of the N-terminal amino acid residues of the recombinant Factor C (HEK, Sf9) were determined. These amino acid sequences are identical to the sequence of the native Factor C of *Tachypleus tridentatus*, reported by the reference (data not shown).

[0148]

Generally, the molecular weight of protein is thought to vary considerably by modification after translation. In addition, it has also been reported that the structure of an N-type sugar chain added to protein through modification after translation differs between the case of insect cells and the case of mammalian cells. Thus, in order to confirm whether the above-observed difference in molecular weight among the purified Factor C proteins is attributed to the difference in N-type sugar chain structure, the Factor C proteins each were treated with glycopeptidase F. This enzyme is known to cleave and remove an N-type sugar chain added to protein. Therefore, when the purified Factor C proteins have the same molecular weight after treatment with the enzyme, N-type sugar chain is conceived to induce the difference in molecular weight among the Factor C proteins.

[0149]

According to an attached instruction, each purified Factor C protein (1 μ g) was treated with 1 mU glycopeptidase F (product of Takara) under modification conditions in the presence of SDS and a reducing agent. The thus-treated samples were separated through SDS-PAGE, and then analyzed

through western blotting. Fig. 13 shows the results. In all cases of the four types of Factor C, the molecular weight of H chain decreased by the glycopeptidase treatment and became the same value. By contrast, although the molecular weight of L chain decreased after the glycopeptidase treatment in all cases of the four types of Factor C, the molecular weight became the same value only in the cases of CHO, HEK, and TAL. Specifically, among four types of L chains, the L chain of the Factor C derived from Sf9 was found to have a molecular weight larger than that of the other three cases, after the glycopeptidase treatment. Therefore, in the L chain of the Factor C derived from Sf9, a certain modification other than N-type sugar chain modification was conceived to occur, after translation.

[0150]

Thus, the aforementioned analysis indicates that the difference in mode of N-type sugar chain after translation plays a main role in providing the difference in molecular weight of Factor C.

[0151]

10. Analysis of N-type sugar chain of Factor C

In N-type sugar chain modification of a protein in mammalian cells, sugar molecules are stepwise added to an asparagine residue of the protein, and eventually, a sugar chain containing terminal sialic acid (i.e., complex-type) is formed. In contrast, in insect cells, sialic acid is not generally added, and a sugar chain having a mannose terminus

(i.e., paucimannose-type) is formed (Robert L. Harrison and Donald L. Jarvis, *Methods in Molecular Biology* 338: 341-356 (2007)). In order to confirm the difference in N-type sugar chain structure among the four types of purified Factor C proteins, lectin blotting was performed by use of various lectins such as terminal sialic acid-specific lectins (e.g., *Maackia amurensis* agglutinin (MAM) and *Sambucus sieboldiana* agglutinin (SSA)).

[0152]

Dilution series (100, 25, and 6 ng) samples of each of the four types of purified Factor C and bovine fetuin protein as a positive control were dot-blotted onto a nitrocellulose membrane, and the membrane was blocked with 3% BSA. Then, the membrane was sequentially reacted with biotin-labeled lectin (product of J-Oil Mills, Inc.) and streptavidin-labeled HRP (product of Thermo Scientific). Light emission attributed to decomposition of the HRP substrate (product of Thermo Scientific) was detected. Instead of lectin, a 2C12 anti-Factor C antibody was used as a control, to thereby confirm that the same amounts of four types of Factor C were blotted.

[0153]

Fig. 14(a) shows the results of lectin blotting, and Fig. 14(b) shows the binding specificity of lectins employed. *Lens culinaris* agglutinin (LCA) (fucose-specific lectin) and *Canavalia ensiformis* agglutinin (Con A) (bi-antenna-type, high-mannose-type, and complex-type sugar chain-specific

lectin) were bonded to all the samples; i.e., four types of Factor C and fetuin. In contrast, MAM ((α -2,3)-linked terminal sialic acid-specific lectin) was strongly bonded to CHO and less strongly bonded to HEK. TAL and fetuin have almost the same weak reactivity, but did not react with Sf9. SSA ((α -2,6)-linked terminal sialic acid-specific lectin) reacted with HEK, TAL, and fetuin, but did not react with CHO and Sf9.

[0154]

The above analysis indicates that the N-type sugar chain of recombinant Factor C expressed in mammalian cells (CHO and HEK) contains (α -2,3)-linked terminal sialic acid, and that the N-type sugar chain of recombinant Factor C expressed in insect cells (Sf9) contains no (α -2,3)-linked terminal sialic acid. Fig. 14(c) shows schematic structures of the N-type sugar chain of recombinant Factor C, estimated by the results of the above experiments and reports by the reference. The results of the above experiments support that the difference in mode of N-type sugar chain modification after translation is mainly attributed to the difference in molecular weight of Factor C.

Industrial Applicability

[0155]

According to the present invention, a recombinant horseshoe crab Factor C can be efficiently produced. In an embodiment of the present invention, endotoxin present in a

test specimen containing an ion can be measured, while inhibition of reaction is reduced.

[0156]

Sequence listing

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

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

SEQ ID NO: 3: DNA sequence of the Factor C gene of Southeast Asian (Singaporean) horseshoe crab

SEQ ID NO: 4: Amino acid sequence of the Factor C of Southeast Asian (Singaporean) horseshoe crab

SEQ ID NO: 5: DNA sequence of the Factor B gene of Japanese horseshoe crab

SEQ ID NO: 6: Amino acid sequence of the Factor B of Japanese horseshoe crab

SEQ ID NO: 7: DNA sequence of the Pro-clotting enzyme gene of Japanese horseshoe crab

SEQ ID NO: 8: Amino acid sequence of the Pro-clotting enzyme of Japanese horseshoe crab

SEQ ID NO: 9: DNA sequence of a Factor B gene of Japanese horseshoe crab, the gene having a codon optimized for expression in insect cells

SEQ ID NO: 10: Peptide sequence

Claims

1. A method for imparting a salt ion resistance for a horseshoe crab Factor C, the method comprising:

recombinantly expressing and secreting the horseshoe crab Factor C into a culture broth or a culture supernatant using a mammalian cell as a host cell, and

recovering the recombinant horseshoe crab Factor C secreted from the mammalian cell,

wherein the horseshoe crab Factor C recombinantly expressed and secreted using the mammalian cell contains (α -2,3)-linked terminal sialic acid in a greater amount, as compared with a corresponding horseshoe crab Factor C expressed using a Sf9 insect cell as a host cell,

wherein the mammalian cell is a Chinese hamster ovary (CHO) cell or a human embryonic kidney (HEK) cell, and

wherein the horseshoe crab Factor C recombinantly expressed and secreted into a culture broth or a culture supernatant using the mammalian cell is a protein selected from the following (A), (B), (C), or (D):

(A) a protein comprising the amino acid sequence of Factor C of *Tachypleus tridentatus*, wherein the protein has no peptide added to the N-terminus of Factor C of *Tachypleus tridentatus*, and wherein the protein has activity of Factor C;

(B) a protein comprising the amino acid sequence of Factor C of *Limulus polyphemus*, wherein the protein has no peptide added to the N-terminus of Factor C of *Limulus polyphemus*, and wherein the protein has activity of Factor C;

(C) a protein comprising the amino acid sequence of Factor C of *Carcinoscorpius rotundicauda*, wherein the protein has no peptide added to the N-terminus of Factor C of *Carcinoscorpius rotundicauda*, and wherein the protein has activity of Factor C;

(D) a protein comprising the amino acid sequence of Factor C of *Tachypleus gigas*, wherein the protein has no peptide added to the N-terminus of Factor C of *Tachypleus gigas*, and wherein the protein has activity of Factor C.

2. The method according to claim 1, wherein the salt ion is

selected from the group consisting of sodium ion, potassium ion, calcium ion, and magnesium ion.

3. The method according to claim 1, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 21 mM sodium citrate as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

4. The method according to claim 1, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 52 mM sodium hydrogencarbonate as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

5. The method according to claim 1, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 214 mM sodium chloride as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

6. The method according to claim 1, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 16 mM magnesium sulfate as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

7. The method according to claim 1, wherein the protein comprises the amino acid sequence of Factor C of *Tachypleus tridentatus*, *Limulus polyphemus*, or *Carcinoscorpius rotundicauda*.

8. A method for producing an endotoxin assay agent comprising a horseshoe crab Factor C, the method comprising:

recombinantly expressing and secreting the horseshoe crab Factor C into a culture broth or a culture supernatant using a mammalian cell as a host cell, recovering the recombinant horseshoe crab Factor C secreted from the mammalian cell, and

producing an endotoxin assay agent comprising the recombinant horseshoe crab Factor C, wherein the horseshoe crab Factor C recombinantly expressed and secreted using the mammalian cell contains (α -2,3)-linked terminal sialic acid in a greater amount, as compared with a corresponding horseshoe crab Factor C expressed using a Sf9 insect cell as a host cell,

wherein the mammalian cell is a Chinese hamster ovary (CHO) cell or a human embryonic kidney (HEK) cell, and

wherein the horseshoe crab Factor C recombinantly expressed and secreted into a culture broth or a culture supernatant using the mammalian cell is a protein selected from the following (A), (B), (C), or (D):

(A) a protein comprising the amino acid sequence of Factor C of *Tachypleus tridentatus*, wherein the protein has no peptide added to the N-terminus of Factor C of *Tachypleus tridentatus*, and wherein the protein has activity of Factor C;

(B) a protein comprising the amino acid sequence of Factor C of *Limulus polyphemus*, wherein the protein has no peptide added to the N-terminus of Factor C of *Limulus polyphemus*, and wherein the protein has activity of Factor C;

(C) a protein comprising the amino acid sequence of Factor C of *Carcinoscorpius rotundicauda*, wherein the protein has no peptide added to the N-terminus of Factor C of *Carcinoscorpius rotundicauda*, and wherein the protein has activity of Factor C;

(D) a protein comprising the amino acid sequence of Factor C of *Tachypleus gigas*, wherein the protein has no peptide added to the N-terminus of Factor C of *Tachypleus gigas*, and wherein the protein has activity of Factor C.

9. The method according to claim 8, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 21 mM sodium citrate as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

10. The method according to claim 8, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 52 mM

sodium hydrogencarbonate as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

11. The method according to claim 8, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 214 mM sodium chloride as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

12. The method according to claim 8, wherein the horseshoe crab Factor C recombinantly expressed and secreted using a mammalian cell exhibits a higher residual activity in the presence of 16 mM magnesium sulfate as compared with a corresponding horseshoe crab Factor C expressed in a Sf9 insect cell as a host cell.

13. The method according to claim 8, wherein the protein comprises the amino acid sequence of Factor C of *Tachypleus tridentatus*, *Limulus polyphemus*, or *Carcinoscorpius rotundicauda*.