DESCRIPTION

METHOD FOR PRODUCING INFLUENZA HA SPLIT VACCINE

TECHNICAL FIELD

[0001]

The present invention relates to a method for producing an influenza HA split vaccine.

BACKGROUND ART

[0002]

Current influenza haemagglutinin (hereinafter also abbreviated as "HA") vaccines induce an anti-HA antibody, thereby exerting a protective effect against infection. The anti-HA antibody binds to a portion of a virus called a "head region" externally exposed from a virus membrane. This region most frequently undergoes structural change in a viral strain. Therefore, in some cases, the anti-HA antibody may fail to bind to a virus which causes antigenic variation and is different from the vaccine strain, and the vaccine cannot exert the protective effect against the infection.

[0003]

Recently, it has been revealed that antibodies that bind to a stem region which is less likely to cause antigenic variation include protective antibodies against infection (Patent Document 1). In order to efficiently induce the antibody that binds to the stem region, an HA stem protein having a stabilized stem portion has been developed, and its clinical trial in humans has been carried out: the stem portion, which is originally unstable, has been stabilized through artificial variation or binding of linkers.

[0004]

However, problems about the production for practical use still remain to be solved, and

development of an HA vaccine antigen that can induce an anti-stem antibody more easily has been expected.

CITATION LIST

PATENT DOCUMENT

[0005]

Patent Document 1: Japanese Unexamined Patent Publication (Translation of PCT International Application) No. 2016-516090

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0006]

In view of the foregoing, it is an object of the present invention to provide a method for producing an influenza HA split vaccine which produces an antibody that binds to an HA stem region, which is less likely to cause antigenic variation, of influenza.

SOLUTION TO THE PROBLEM

[0007]

The method for producing an HA split vaccine according to the present invention includes subjecting an influenza HA split vaccine to an acidic treatment, thereby producing an influenza HA split vaccine which produces an antibody that binds to a long alpha helix (LAH) of an HA stem region, and is effective against an influenza virus that causes antigenic variation.

[0008]

Specifically, the present invention relates to the following.

[Item 1]

A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method including: subjecting an influenza HA split vaccine to an acidic treatment.

[Item 1a]

A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method including: subjecting an influenza HA split vaccine, which has not undergone a formalin treatment, to an acidic treatment.

[Item 1b]

A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method including: subjecting an influenza HA split vaccine to an acidic treatment; and thereafter, subjecting the influenza HA split vaccine to a formalin treatment.

[Item 1c]

A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method including: subjecting an influenza HA split vaccine, which has not undergone a formalin treatment, to an acidic treatment; and thereafter, subjecting the influenza HA split vaccine to a formalin treatment.

[Item 2]

The production method according to Items 1, 1a to 1c, wherein the influenza HA split vaccine is also effective against an influenza virus that causes antigenic variation.

[Item 3]

A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region and which is effective against an influenza virus that causes antigenic variation, the method including: subjecting an influenza HA split vaccine to an acidic treatment.

[Item 4]

The method of any one of Items 1 to 3, 1a to 1c wherein the acidic treatment is performed at a pH of 4.4 to 5.8.

[Item 5]

The method of any one of Items 1 to 4, 1a to 1c wherein the influenza HA split vaccine is of type H3N2 or type H1N1.

[Item 5c]

The method of any one of Items 1 to 5 and 1a to 1c wherein the influenza HA split vaccine is of type H3N2 or type H1N1, except for the method including steps: a treatment is performed by adding 0.15 M citrate buffer (pH 3.5) to an influenza HA split vaccine of type H3N2 or type H1N1 suspended in phosphate buffered saline to bring the pH to 5.0; after 30 minutes at room temperature, 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3; centrifugation is performed to obtain a membrane fusion-type HA split vaccine; and then formalin is added to the membrane fusion-type HA split vaccine to a final concentration of 0.05 v/v%, and left stand for several days.

[Item 5d]

The method of any one of Items 1 to 5 and 1a to 1c wherein the influenza HA split vaccine is of type H3N2 or type H1N1, except for the method including steps: a treatment is performed by adding 0.15 M citrate buffer (pH 3.5) to an influenza HA split vaccine prepared from strain X31 of type H3N2 or strain A/Puerto Rico/8/34 of type H1N1 suspended in phosphate buffered saline to bring the pH to 5.0; after 30 minutes at room temperature, 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3; centrifugation is performed to obtain a membrane fusion-type HA split vaccine; and then formalin is added to the membrane fusion-type HA split vaccine to a final concentration of 0.05 v/v%, and left stand for several days.

[Item 5a]

The method according to any one of Items 1 to 5, 1a to 1c, 5c and 5d wherein the influenza HA split vaccine is an influenza HA split vaccine of a single HA subtype.

[Item 5b]

The method according to any one of Items 1 to 5, 1a to 1c, 5c and 5d the method including: mixing two or more of influenza HA split vaccine antigens, each of which is produced by subjecting an influenza HA split vaccine of a single subtype to an acidic treatment.

[Item 6]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region.

[Item 7]

The influenza HA split vaccine of Item 6, which is also effective against an influenza virus that causes antigenic variation.

[Item 8]

The influenza HA split vaccine of Item 6 or 7, which has an HA stem region exposed outside.

[Item 9]

The influenza HA split vaccine of any one of Items 6 to 8, wherein the HA stem region of the influenza HA split vaccine antigen, which is exposed outside, enhances the antigenicity of the LAH of the HA stem region, and the influenza HA split vaccine is capable of producing an antibody that binds to the LAH of the HA stem region.

[Item 10]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being produced by subjecting an influenza HA split vaccine to an acidic treatment.

[Item 10a]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being produced by subjecting an influenza HA split vaccine, which has not undergone a formalin treatment, to an acidic treatment.

[Item 10b]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being produced by a production process including: subjecting an influenza HA split vaccine to an acidic treatment; and thereafter, subjecting the influenza HA split vaccine to a formalin treatment.

[Item 10c]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being produced by a production process including: subjecting an influenza HA split vaccine, which has not undergone a formalin treatment, to an acidic treatment; and thereafter, subjecting the influenza HA split vaccine to a formalin treatment.

[Item 10d]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being produced by subjecting an influenza HA split vaccine including a single subtype to an acidic treatment.

[Item 10e]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being a vaccine antigen produced by mixing two or more of influenza HA split vaccine antigens each of which is produced by subjecting an influenza HA split vaccine including a single subtype to an acidic treatment.

[Item 10f]

An influenza HA split vaccine of any one of Items 10 to 10e, which is also effective

against an influenza virus that causes antigenic variation.

[Item 10g]

The influenza HA split vaccine of any one of Items 10 to 10f which is produced by the method of Items 5c or 5d.

[Item 11]

An influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, and is also effective against an influenza virus that causes antigenic variation, the vaccine being produced by subjecting an influenza HA split vaccine to an acidic treatment.

[0009]

One embodiment of the present application includes a method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method A described below.

Production method A including steps: Polyoxyethylene sorbitan monooleate (for example Tween 80) is added to strain X31 of type H3N2 or strain A/Puerto Rico/8/34 of type H1N1 suspended in phosphate buffered saline to a final concentration of 0.1 v/v%, and suspended therein; diethyl ether is added and suspended, and the suspension is left stand until an aqueous layer and a diethyl ether layer are completely separated, and then the diethyl ether layer is removed; diethyl ether remaining in the recovered aqueous layer is distilled off at normal pressure to obtain an HA split vaccine; a treatment is then performed by adding 0.15 M citrate buffer (pH 3.5) to the HA split vaccine suspended in phosphate buffered saline to bring the pH to 5.0; after 30 minutes at room temperature, 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3; centrifugation is performed to obtain a membrane fusion-type HA split vaccine; and then formalin is added to the membrane fusion-type HA split vaccine to a final concentration of 0.05 v/v%.

[0010]

One embodiment of the present application includes an influenza HA split vaccine which is produced by the method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method A.

[0011]

One embodiment of the present application includes an influenza HA split vaccine according to any one of Items 6 to 11 and 10a to 10f except for an influenza HA split vaccine which is produced by Production method A.

[0012]

One embodiment of the present application includes a method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method B described below.

Production method B including steps: Polyoxyethylene sorbitan monooleate (for example Tween 80) is added to particles of H3N2 influenza virus or particles of H1N1 influenza virus suspended in phosphate buffered saline to a final concentration of 0.1 v/v%, and suspended therein; diethyl ether is added and suspended, and the suspension is left stand until an aqueous layer and a diethyl ether layer are completely separated, and then the diethyl ether layer is removed; diethyl ether remaining in the recovered aqueous layer is distilled off at normal pressure to obtain an HA split vaccine; a treatment is then performed by adding 0.15 M citrate buffer (pH 3.5) to the HA split vaccine suspended in phosphate buffered saline to bring the pH to 5.0; after 30 minutes at room temperature, 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3; centrifugation is performed to obtain a membrane fusion-type HA split vaccine; and then formalin is added to the membrane fusion-type HA split vaccine to a final concentration of 0.05 v/v%.

[0013]

One embodiment of the present application includes an influenza HA split vaccine which is produced by the method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method B.

[0014]

One embodiment of the present application includes an influenza HA split vaccine according to any one of Items 6 to 11 and 10a to 10f except for an influenza HA split vaccine which is produced by Production method B.

[0015]

One embodiment of the present application includes a method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method C described below.

Production method C including steps: a treatment is performed by adding 0.15 M citrate buffer (pH 3.5) to an influenza HA split vaccine prepared from strain X31 of type H3N2 or strain A/Puerto Rico/8/34 of type H1N1 suspended in phosphate buffered saline to bring the pH to 5.0; after 30 minutes at room temperature, 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3; centrifugation is performed to obtain a membrane fusion-type HA split vaccine; and then formalin is added to the membrane fusion-type HA split vaccine to a final concentration of 0.05 v/v%.

[0016]

One embodiment of the present application includes an influenza HA split vaccine which is produced by the method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method C.

[0017]

One embodiment of the present application includes an influenza HA split vaccine according to any one of Items 6 to 11 and 10a to 10f except for an influenza HA split vaccine

which is produced by Production method C.

[0018]

One embodiment of the present application includes a method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method D described below.

Production method D including steps: a treatment is performed by adding 0.15 M citrate buffer (pH 3.5) to an influenza HA split vaccine of type H3N2 or type H1N1 suspended in phosphate buffered saline to bring the pH to 5.0; after 30 minutes at room temperature, 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3; centrifugation is performed to obtain a membrane fusion-type HA split vaccine; and then formalin is added to the membrane fusion-type HA split vaccine to a final concentration of 0.05 v/v%.

[0019]

One embodiment of the present application includes an influenza HA split vaccine which is produced by the method for producing an influenza HA split vaccine according to any one of Items 1 to 5, 1a to 1c, 5a and 5b except for Production method D.

[0020]

One embodiment of the present application includes an influenza HA split vaccine according to any one of Items 6 to 11 and 10a to 10f except for an influenza HA split vaccine which is produced by Production method D.

ADVANTAGES OF THE INVENTION

[0021]

According to the present invention, an influenza HA split vaccine which produces an antibody that binds to an HA stem region of influenza is obtained by a simple technique, the HA stem region being less likely to cause antigenic variation. Therefore, an influenza HA split

vaccine which is also effective against an influenza virus which causes antigenic variation is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

[FIG. 1] FIG. 1 is a schematic diagram illustrating an influenza virus.

[FIG. 2] FIG. 2 is a graph showing an increase in the titer of an anti-LAH antibody in sera of mice inoculated with a membrane fusion-type H3N2 HA split vaccine.

[FIG. 3] FIG. 3 is a graph showing an improvement in the cross-protective capacity of mice inoculated with the membrane fusion-type H3N2 HA split vaccine against an antigenic variant.

[FIG. 4] FIG. 4 is a graph showing an increase in the titer of an anti-LAH antibody in sera of mice inoculated with a membrane fusion-type H1N1 HA split vaccine.

[FIG. 5] FIG. 5 is a graph showing an improvement in the cross-protective capacity of mice inoculated with the membrane fusion-type H1N1 HA split vaccine against an antigenic variant.

[FIG. 6] FIG. 6 shows graphs each indicating that an LAH binding monoclonal antibody binds more strongly to a membrane fusion-type HA split vaccine than to a current HA split vaccine.

[FIG. 7] FIG. 7 shows graphs each indicating that the LAH binding monoclonal antibody strongly binds to a membrane fusion-type HA split vaccine that has been subjected to a formalin treatment after an acidic treatment.

[FIG. 8] FIG. 8 is a graph showing an increase in the titer of an anti-LAH antibody in sera of mice inoculated with membrane fusion-type H3N2 HA split vaccines ((Pre-fix) and (Post-fix)).

DESCRIPTION OF EMBODIMENTS

[0023]

Embodiments of the present invention will be described in detail below with reference to the accompanying drawings. However, the embodiments are intended to facilitate understanding of the principle of the present invention, and the scope of the invention is not limited to the following embodiments. Other embodiments, in which the configuration of the following embodiments has been appropriately replaced by those skilled in the art, are also encompassed in the scope of the present invention.

[0024]

The method for producing an influenza HA split vaccine according to this embodiment includes a step of subjecting an influenza HA split vaccine to an acidic treatment.

[0025]

An influenza HA split vaccine is prepared through a treatment of a whole-virus vaccine with ether to remove lipid components which become pyrogens. The influenza HA split vaccine has HA protein as the main ingredient because the influenza HA split vaccine is produced by collecting the HA protein, which is required for immunization, from the surfaces of the virus particles by density gradient centrifugation.

[0026]

Glycoprotein called "spike protein" protrudes from the surface of an influenza virus (FIG. 1). An influenza A virus has two types of spike proteins, namely, HA and NA (neuraminidase), which help the virus cause the infection. HA binds to a cell to be infected and helps the entry of the virus into the cell. HA frequently causes antigenic variation. NA unbinds the infected cell from HA, and serves to release the replicated viruses from the cell.

[0027]

HA of the influenza A virus is divided into two regions, namely, a head region and a stem region (FIG. 1). The head region contains a receptor binding site at which the virus binds to a target cell. The stem region contains a fusion peptide sequence necessary for membrane fusion between the viral membrane and the cell membrane of the target cell.

[0028]

An acidic treatment on the influenza HA split vaccine changes the structure of the HA protein to a structure called membrane fusion-type. In the membrane fusion-type HA protein, the stem region is exposed outside from the viral membrane instead of the head region, with a large structural change in the conformation of an antigen stem. The present inventors have found in vivo that when the membrane fusion-type HA protein is used as a vaccine, an antibody that binds to an LAH of the stem region is induced, and that this antibody has a protective effect against a virus strain that causes antigenic variation. The present invention has been made based on this fact.

[0029]

The acidic treatment is not particularly limited, and may be performed at a pH of, for example, 2.0 to 6.5, preferably 3.0 to 6.5, more preferably 4.0 to 6.0, and more preferably 4.4 to 5.8. Specific examples includes pH2.0 to 2.9, 2.0 to 4.0, 2.0 to 5.0, 2.0 to 6.0, 3.0 to 4.0, 3.0 to 5.0, 3.0 to 6.0, 4.0 to 5.8, 4.0 to 6.5, 5.0 to 6.5, and 6.0 to 6.5. The acid for use in the acidic treatment is not particularly limited, and may be, for example, phosphoric acid, citric acid, maleic acid, hydrochloric acid, or any other suitable acid.

[0030]

The temperature of an acidic treatment is, for example, 0°C to 75°C, preferably 10°C to 60°C, more preferably 20°C to 45°C, and more preferably 25°C to 42°C. Specific examples include 0°C to 20°C, 5°C to 25°C, 10°C to 30°C, 15°C to 35°C, 20°C to 37°C, 25°C to 37°C, 30°C to 50°C, 38°C to 55°C, 38°C to 60°C, 38°C to 65°C, 38°C to 70°C, 38°C to 75°C, 40°C

to 55°C, 40°C to 60°C, 40°C to 65°C, 40°C to 70°C, 40°C to 75°C, 42°C to 55°C, 42°C to 60°C, 42°C to 65°C, 42°C to 70°C, 42°C to 75°C, 45°C to 55°C, 45°C to 60°C, 45°C to 65°C, 45°C to 70°C, and 45°C to 75°C. The time of the treatment is, for example, 5 minutes to 120 minutes, preferably 15 minutes to 60 minutes, more preferably 20 minutes to 45 minutes. Specific examples include 5 minutes to 60 minutes, 20 minutes to 60 minutes, 15 minutes to 120 minutes, 15 minutes to 45 minutes, 20 minutes to 60 minutes, 20 minutes to 120 minutes, 45 minutes to 120 minutes, and 60 minutes to 120 minutes.

[0031]

Based on differences in antigenicity, HA of the influenza A virus is classified into 18 subtypes (H1 to H18), and NA into 9 subtypes (N1 to N9). The influenza HA split vaccine of the present invention is applicable to all of these subtypes. In addition, the method for producing the influenza HA split vaccine according to the present invention can produce a vaccine which is effective against not only the influenza A virus, but also an influenza B virus having HA.

[0032]

The influenza split HA vaccine obtained by the production method according to the present invention produces an antibody that binds to an LAH which is less likely to cause variation. Therefore, the vaccine can be cross-protective against an influenza virus, which is known as an antigenic variant, as long as the virus has the same HA subtype. Furthermore, the influenza split HA vaccine obtained by the production method according to the present invention may be cross-reactive between HA subtypes of similar amino acid sequences of LAH (e.g., H3 and H7).

[0033]

In the present application, an "influenza HA split vaccine of a single HA subtype" refers to an influenza HA split vaccine of a single HA subtype which is selected from the 18 subtypes (H1 to H18) of the influenza A virus, or the influenza B virus. As long as with the

single HA subtype, the NA subtypes may be identical or different. Preferred HA subtypes include H1, H3, and B.

[0034]

To produce a mixed vaccine containing two or more HA subtypes, influenza HA split vaccines each of which is of a single HA subtype are subjected to an acidic treatment, and a plurality of (two or more) influenza HA split vaccines thus obtained can be mixed together. Alternatively, a mixed vaccine can also be produced by performing an acidic treatment on an influenza HA split vaccine previously prepared by mixing vaccines of two or more HA subtypes. To inoculate the vaccine as a vaccine including two or more subtypes, the vaccine preferably includes one to three subtypes selected from the group consisting of H1, H3, and B.

[0035]

In a preferred embodiment, the influenza HA split vaccine obtained by the production method of the present invention binds to an LAH binding monoclonal antibody more strongly than a current HA split vaccine. For example, the influenza HA split vaccine binds to the LAH binding monoclonal antibody at least 1.05 times, preferably at least 1.1 times, more preferably at least 1.5 times, and even more preferably at least two times more strongly than the current HA split vaccine. In this context, "the influenza HA split vaccine binds at least 1.05 times, at least 1.1 times, at least 1.5 times, or at least two times more strongly than the current HA split vaccine" means, for example, that the reciprocal of the antibody concentration at the time when an absorbance determined by regression is 0.7 is at least 1.05 times, at least 1.1 times, at least 1.5 times, or at least two times the reciprocal of the antibody concentration of the current HA split vaccine. In a preferred embodiment, the binding capacity of the influenza HA split vaccine of the present invention to the LAH binding monoclonal antibody is higher than that of the current HA split vaccine. Although the upper limit is not particularly limited, the binding capacity may be in a range of, for example, 1.05 to 200 times, 1.1 to 150 times, 1.5 to 100 times,

or 2 to 50 times. Alternatively, the range of the binding capacity of the influenza HA split vaccine of the present invention to the LAH binding monoclonal antibody compared to that of the current HA split vaccine may be indicated by a combination of the lower limit value selected from 1.05, 1.1, 1.5, 2, 3, 4, and 5 and the upper limit value selected from 200, 150, 100, 50, 30, and 20. For the measurement of the binding capacity of the influenza HA split vaccine to the LAH binding monoclonal antibody, any method can be used without particular limitations, and a common method known to those skilled in the art can be employed. For example, the binding capacity can be measured by a method described in examples of the present application.

[0036]

In the present application, the "LAH binding monoclonal antibody" means a monoclonal antibody which binds to the LAH. For the production of the monoclonal antibody, any method may be used without particular limitations, and a common method known to those skilled in the art may be employed. In the measurement of the binding capacity of the influenza HA split vaccine to the LAH binding monoclonal antibody, it is assumed that the LAH binding monoclonal antibody is capable of binding to a peptide corresponding to at least a portion of the LAH of an influenza virus from which the influenza HA split vaccine is derived.

[0037]

In this application, the "current HA split vaccine" means a vaccine from which lipid components that become pyrogens are removed through a treatment of the whole-virus vaccine with ether, and can be produced by a method described in Example 1 of the present application, for example. The current HA split vaccine may also be an influenza HA split vaccine produced without being subjected to an acidic treatment, in contrast with the influenza HA split vaccine of the present invention prepared by a method including the following acidic treatment.

[0038]

The production of the influenza HA split vaccine of the present invention may include

performing a formalin treatment. In a preferred embodiment, the acidic treatment of the influenza HA split vaccine is performed before the formalin treatment. In preparing an influenza HA split vaccine antigen of the present invention (an influenza HA split vaccine antigen capable of producing an antibody that binds to the LAH of the HA stem region), an HA fraction for use for the current influenza HA split vaccine is subjected to an acidic treatment, and then to a formalin treatment. This makes it possible to obtain an influenza HA split vaccine antigen which produces a cross-reactive antibody more effectively, and thus, is more preferable as a universal influenza vaccine antigen. That is, in a preferred embodiment of the present application, an HA fraction from which fat solvents are removed through a treatment of the virus particles with ether or any other appropriate agents is subjected to an acidic treatment, and then to a formalin treatment.

[0039]

In a preferred embodiment of the present application, the influenza HA split vaccine before the acidic treatment is a split vaccine which has not undergone the formalin treatment.

[0040]

Commercially available Influenza HA Vaccine (trade name) has already undergone a treatment with formaldehyde or a substance having an equivalent action after the virus is decomposed by ether or any other appropriate agents and fat solvents are removed, as described in Biological Products Standards (March 30, 2004, Ministerial Notification No. 155 of Ministry of Health, Labor and Welfare, most recent revision on November 30, 2018, Ministerial Notification No. 409). It is preferable not to use the commercially available Influenza HA Vaccine (trade name), which is one of the influenza HA split vaccines, for the production of the influenza HA split vaccine of the present invention because it has already been treated with formaldehyde or any other appropriate agents.

[0041]

The concentration of formalin in a formalin treatment solution for used in the formalin treatment of the influenza HA split vaccine after the acidic treatment is, for example, 0.0005 v/v% to 10 v/v%, preferably 0.001 v/v% to 1 v/v%, more preferably 0.003 v/v% to 0.5 v/v%, and still more preferably 0.005 v/v% to 0.1 v/v%. The time of the formalin treatment is for example, 1 hour to 10 days, preferably 2 hours to 5 days, more preferably 12 hours to 3 days. The temperature of the formalin treatment is, for example 0°C to 75°C, preferably 1°C to 37°C, more preferably 1°C to 30°C.

[0042]

It is preferable to use formalin of a medical grade.

[0043]

The method for producing the influenza HA split vaccine of the present invention may include a step of adding an adjuvant. Examples of the adjuvant include, but are not limited to, aluminum salts such as aluminum hydroxide and aluminum phosphate, chitosan, oligodeoxynucleotides, and oil-in-water emulsions. Among them, aluminum hydroxide is preferred, and use of aluminum hydroxide as the adjuvant can enhance the immunogenicity.

[0044]

The influenza HA split vaccine obtained by the production method of the present invention can be used, for example, for additional inoculation after a predetermined period after the initial inoculation. The period after the initial inoculation and before the additional inoculation is not particularly limited, but may be, for example, twenty days to three years, preferably three months to two years, more preferably six months to one year. The amount of the influenza HA split vaccine for the initial and additional inoculations is not particularly limited, but may be, for example, 1 μg to 200 μg, preferably 10 μg to 30 μg, more preferably 15 μg, per dose. A single dose is, for example, 0.5 mL. Any administration method may be used

for the initial and additional inoculations without particular limitations, and for example, nasal, subcutaneous, intradermal, transdermal, intraocular, mucosal, or oral administration may be employed. Intramuscular administration is preferred.

[0045]

The influenza HA split vaccine obtained by the production method of the present invention has a protective effect against a virus strain that causes antigenic variation. For example, if a current HA split vaccine is prepared from particles of H3N2 influenza virus (A/Fujian/411/02 (H3N2)) and subjected to an acidic treatment, the vaccine may have a protective effect against infection of not only A/Fujian/411/02 (H3N2), but also A/Guizhou/54/89 (H3N2), A/OMS/5389/88 (H3N2), A/Beijing/32/92 (H3N2), A/England/427/88 (H3N2), A/Johannesburg/33/94 (H3N2), A/Leningrad/360/86 (H3N2), A/Mississippi/1/85 (H3N2), A/Philippines/2/82 (H3N2), A/Shangdong/9/93 (H3N2), A/Shanghai/16/89 (H3N2), A/Shanghai/24/90 (H3N2), A/Sichuan/2/87 (H3N2), A/Kitakyushyu/159/93 (H3N2), A/Akita/1/94 (H3N2), A/Panama/2007/99 (H3N2), A/Wyoming/03/03 (H3N2), A/New York/55/2004 (H3N2), or A/Hiroshima/52/2005 (H3N2) , for example. Also, for example, if a current HA split vaccine is prepared from particles of H1N1 influenza virus (A/Puerto Rico/8/34 (H1N1)) and subjected to an acid treatment, the vaccine may also have a protective effect against infection of not only A/Puerto Rico/8/34 (H1N1), but also A/Narita/1/09 (H1N1), A/Beijing/262/95 (H1N1), A/Brazil/11/78 (H1N1), A/Chile/1/83 (H1N1), A/New Jersey/8/76 (H1N1), A/Taiwan/1/86 (H1N1), A/Yamagata/32/89 (H1N1), A/New Caledonia/20/99 (H1N1), A/Solomon Islands/3/2006 (H1N1), A/Brisbane/59/2007 (H1N1), or A/Mexico/4108/2009 (H1N1), for example.

Example

[0046]

1. Preparation of HA Split Vaccine

Tween 80 was added to particles of H3N2 influenza virus (strain X31) or particles of H1N1 influenza virus (A/Puerto Rico/8/34 strain) suspended in phosphate buffered saline to a final concentration of 0.1 v/v%, and suspended therein. Diethyl ether was added and suspended, and the suspension was left stand until an aqueous layer and a diethyl ether layer were completely separated, and then the diethyl ether layer was removed. After repeating this ether extraction, diethyl ether remaining in the recovered aqueous layer was distilled off at normal pressure to obtain an HA split vaccine.

[0047]

2. Acidic Treatment

The HA split vaccine was suspended in phosphate buffered saline, and an acidic treatment was then performed by adding 0.15 M citrate buffer (pH 3.5) to bring the pH to 5.0. After standing at room temperature for 30 minutes, 1 M Tris buffer (pH 8.0) was added so that the pH was returned to 7.3. Thereafter, centrifugation was performed to obtain a membrane fusion-type HA split vaccine. Formalin was added to the membrane fusion-type HA split vaccine thus prepared to a final concentration of 0.05 v/v%, and left stand for several days.

[0048]

A current HA split vaccine was prepared in the same manner as described in 1 above except that no acidic treatment was provided.

[0049]

3. Measurement of Titer of anti-LAH Antibody by ELISA

3-1. Inoculation of H3N2 Influenza Vaccine

BALB/c mice (female, 6 to 12 weeks old) were intraperitoneally inoculated with the current H3N2 HA split vaccine or the membrane fusion-type HA split vaccine (10 μg of vaccine + 10 v/v% of AddaVax adjuvant (InvivoGen) dissolved in phosphate buffered saline to a liquid volume of 200 μl). Twenty eight days after the initial inoculation, the mice were

intraperitoneally inoculated with the membrane fusion-type HA vaccine (10 μg of the vaccine alone was dissolved in phosphate buffered saline to a liquid volume of 200 μl). At least 14 days after the additional inoculation, blood was collected from the mice inoculated with the vaccine, from which sera were collected.

[0050]

3-2. Measurement by ELISA

The concentration of the anti-LAH antibody in the sera of BALB/c mice intraperitoneally inoculated with the current H3N2 HA split vaccine or the membrane fusion-type HA split vaccine was measured by ELISA (Enzyme-Linked Immuno Sorbent Assay) in the following manner.

[0051]

Specifically, a synthetic peptide (H3; Ac-RIQDLEKYVEDTKIDLWSYNAELLVALENQHTIDLTDSEMNKLFEKTRRQLRENADY KDDDDKC) (SEQ ID NO: 1) corresponding to a portion (long alpha helix) of the stem portion was dissolved in phosphate buffered saline (pH 7.3) at 10 μg/ml, and added to 96-well plates by 100 μl each. After standing overnight at 4°C, each well was washed three times with phosphate buffered saline, and 150 μl of phosphate buffered saline containing 1 v/v% bovine serum albumin was added. After standing at room temperature for two hours, each well was washed three times with phosphate buffered saline. Then, 100 μl of a mouse serum serially diluted with phosphate buffer containing 0.05 v/v% of Tween 20 and 1 v/v% bovine serum albumin, and 100 μl of a standard monoclonal antibody of known concentration (H3; clone name V15-5) were added to each well. After standing at room temperature for two hours, each well was washed three times with phosphate buffered saline (containing 0.05 v/v% of Tween 20), and 100 μl of a peroxidase-labeled anti-mouse IgG antibody (Southern Biotech) diluted with phosphate buffered saline containing 0.05 v/v% Tween 20 and 1 v/v% bovine serum

albumin was added to each well. After standing at room temperature for two hours, each well was washed three times with phosphate buffered saline (containing 0.05 v/v% of Tween 20). Then, 30 mg of o-phenylendiamine tablet (Sigma) and 24 μl of 30% hydrogen peroxide solution (30% w/w; Sigma) were added to 60 ml of citrate buffer (pH 5.0) as a substrate, and 100 μl of the resultant was added to each well. After the color development, 50 μl of 1 mol/L sulfuric acid (Wako Pure Chemical Industries, Ltd.) was added to stop the reaction, and an absorbance value at 490 nm was measured using a Microplate Reader 450 (Biorad).

[0052]

As shown in FIG. 2, the titer of the anti-LAH antibody in the serum of the BALB/c mice intraperitoneally inoculated with the membrane fusion-type HA split vaccine was significantly higher than the titer of the anti-LAH antibody in the serum of BALB/c mice intraperitoneally inoculated with the current HA split vaccine.

[0053]

4. Cross-Protection against Antigenic Variant

In an experiment on protection against infection with the H3N2 virus, 200 μl of a serum collected from uninoculated mice, 200 μl of a serum collected from mice inoculated with the current H3N2 HA split vaccine, or 200 μl of a serum collected from mice inoculated with the membrane fusion-type HA split vaccine was intraperitoneally administered to BALB/c mice (female, 6 to 12 weeks old).

[0054]

Three hours after the serum administration, another H3N2 influenza virus (A/Guizhou/54/89) having different antigenicity from the vaccine strain was intranasally administered at 5 mouse lethal dose 50 (five times the amount of virus lethal to 50% of mice) under anesthesia.

[0055]

Mice were weighed and observed daily for 21 days from the viral infection to study the change in body weight and the survival rate. The humane endpoint was set at 25% body weight loss.

[0056]

As shown in FIG. 3, regarding the BALB/c mice inoculated with the membrane fusion-type HA split vaccine, the decrease in the survival rate was significantly curbed on and after the ninth day after the infection with the other H3N2 influenza virus of different antigenicity.

[0057]

5. Measurement of Titer of anti-LAH Antibody by ELISA

5-1. Particles of H1N1 Influenza Virus

C57BL/6 mice (female, 6 to 12 weeks old) were intraperitoneally inoculated with a current H1N1 HA split vaccine or a membrane fusion-type HA split vaccine (10 μg of vaccine + 10 μg of CpG-ODN 1760 suspended in phosphate buffered saline and mixed with an equal volume of Freund's incomplete adjuvant (ROCKLAND) to a liquid volume of 200 μl). Twenty eight days after the initial inoculation, the mice were intraperitoneally inoculated with the membrane fusion-type HA split vaccine (10 μg of vaccine + 10 μg of CpG-ODN suspended in phosphate buffered saline and mixed with an equal volume of Freund's incomplete adjuvant (ROCKLAND) to a liquid volume of 200 μl, in the same manner as the initial inoculation). At least 14 days after the additional inoculation, blood was collected from the mice inoculated with the vaccine, from which sera were collected.

[0058]

5-2. Measurement by ELISA

The concentration of the anti-LAH antibody in the sera of C57BL/6 mice intraperitoneally inoculated with the current H1N1 HA split vaccine or the membrane fusion-type HA split vaccine was measured by ELISA in the following manner.

[0059]

The measurement was performed in the same manner as described above except that a synthetic peptide (H1; Ac-RIENLNKKVDDGFLDIWTYNAELLVLLENERTLDYHDSNVKNLYEKVRSQLKNNAD YKDDDDKC) (SEQ ID NO: 2) corresponding to a portion (long alpha helix) of the stem portion was used and a standard monoclonal antibody of known concentration (H1; clone name F2) was used.

[0060]

As shown in FIG. 4, the titer of the anti-LAH antibody in the sera of the C57BL/6 mice intraperitoneally inoculated with the membrane fusion-type HA split vaccine was significantly higher than the titer of the anti-LAH antibody in the sera of the C57BL/6 mice intraperitoneally inoculated with the current HA split vaccine.

[0061]

6. Cross-Protection against Antigenic Variant

In an experiment on protection against infection with the H1N1 virus, 200 μl of a serum collected from uninoculated mice, 200 μl of a serum collected from mice inoculated with the current H1N1 HA split vaccine, or 200 μl of a serum collected from mice inoculated with the membrane fusion-type HA split vaccine was intraperitoneally administered to C57BL/6 mice (female, 6 to 12 weeks old).

[0062]

Three hours after the serum administration, another H1N1 influenza virus (A/Narita/1/09) having different antigenicity from the vaccine strain was intranasally administered at 5 mouse lethal dose 50 (five times the amount of virus lethal to 50% of mice) under anesthesia.

[0063]

Mice were observed daily for 20 days from the viral infection to study the survival rate. As shown in FIG. 5, regarding the C57BL/6 mice inoculated with the membrane fusion-type HA split vaccine, the decrease in the survival rate was significantly curbed on and after the ninth day after the infection with the other H1N1 influenza virus of different antigenicity.

[0064]

7. Binding Capacity of Antibody to LAH Epitope

Binding of anti-LAH monoclonal antibodies (#1 to #5 in FIG. 6) prepared from murine or human peripheral blood infected with strain X31 to a current HA split vaccine or a membrane fusion-type HA split vaccine was measured by ELISA (Enzyme-Linked Immuno Sorbent Assay). The current HA split vaccine or membrane fusion-type HA split vaccine of an H3N2 influenza virus (strain X31) was dissolved in phosphate buffered saline (pH 7.3), and added to a 96-well plate by 50 μl each. After standing overnight at 4°C, each well was washed three times with phosphate buffered saline, and 150 μl of phosphate buffered saline containing 1 v/v% bovine serum albumin was added. After standing at room temperature for two hours, each well was washed three times with phosphate buffered saline (containing 0.05 v/v% of Tween 20), and 50 μl of the LAH binding monoclonal antibody serially diluted with phosphate buffer containing 1 v/v% bovine serum albumin was added. After standing overnight at 4°C, each well was washed three times with phosphate buffered saline (containing 0.05 v/v% of Tween 20), and 100 μl of a peroxidase-labeled anti-mouse IgG antibody (Southern Biotech) diluted with phosphate buffered saline containing 0.05 v/v% Tween 20 and 1 v/v% bovine serum albumin was added to each well. After standing at room temperature for two hours, each well was washed three times with phosphate buffered saline (containing 0.05 v/v% of Tween 20). Then, 30 mg of o-phenylendiamine tablet (Sigma) and 24 μl of 30% hydrogen peroxide solution (30% w/w; Sigma) were added to 60 ml of citrate buffer (pH 5.0) as a substrate, and 50 μl of the resultant was added to each well. After the color development, 25 μL of 1 mol/L sulfuric acid

(Wako Pure Chemical Industries, Ltd.) was added to stop the reaction, and an absorbance value at 490 nm was measured using Microplate Reader 450 (Biorad). The change in binding capacity was calculated from the absorbance values measured with respect to the current HA split vaccine or the membrane fusion-type HA split vaccine.

[0065]

As shown in FIG. 6, the binding capacity of the LAH binding monoclonal antibody to the membrane fusion-type HA split vaccine was 1.05 to 21 times greater than the binding capacity to the current HA split vaccine. The results show that an acidic treatment of the HA split vaccine enhances the binding capacity of the antibody to the LAH epitope.

[0066]

8. Influence of Order of Formalin Treatment on Binding Capacity of Antibody and Antibody Inducibility

8-1. Preparation of Formalin-Pretreated HA Split Vaccine

To particles of H3N2 influenza virus (strain X31) suspended in phosphate buffered saline, Tween 80 was added and suspended in a final concentration of 0.1 v/v%. Diethyl ether was added and suspended, and the suspension was left stand until an aqueous layer and a diethyl ether layer were completely separated, and then the diethyl ether layer was removed.
After repeating this ether extraction, diethyl ether remaining in the recovered aqueous layer was distilled off at normal pressure. Further, formalin was added at a final concentration of 0.05 v/v%, and the mixture was left stand for several days to obtain a formalin-pretreated HA split vaccine.

[0067]

8-2. Acidic Treatment of Formalin-Pretreated HA Split Vaccine

The formalin-pretreated HA split vaccine was suspended in phosphate buffered saline, and then an acidic treatment was performed by adding 0.15 M citrate buffer (pH 3.5) to bring

the pH to 5.0. After standing at room temperature for 30 minutes, 1 M Tris buffer (pH 8.0) was added so that the pH was returned to 7.3. Thereafter, centrifugation was performed.

[0068]

9. Binding Capacity of Antibody to LAH Epitope

The binding capacity of the antibody to the LAH epitope was measured in the same manner as described in the above 7, and the change in the binding capacity was calculated. Here, the same antibodies as #2, #4 and #5 shown in FIG. 6 were used as the monoclonal antibodies, and the monoclonal antibody #6 which binds to the HA head region was used as a control.

[0069]

10. Measurement of Titer of anti-LAH Antibody by ELISA

10-1. Inoculation of H3N2 Influenza Vaccine

BALB/c mice (female, 6 to 12 weeks old) were intraperitoneally inoculated with the current H3N2 HA split vaccine or the membrane fusion-type HA split vaccine (10 μg vaccine + 10 v/v% AddaVax adjuvant (InvivoGen) dissolved in phosphate buffered saline to a liquid volume of 200 μl). At least 12 days after the inoculation, blood was collected from the mice inoculated with the vaccines, from which sera were collected.

[0070]

10-2. Measurement by ELISA

The titer of the anti-LAH antibody was measured in the same manner as described in the above 3-2.

[0071]

As shown in FIG. 7, the LAH binding monoclonal antibody bound to the vaccine (Post-fix) that had undergone the formalin treatment after the acidic treatment in the process of preparing the membrane fusion-type HA split vaccine more strongly than to the vaccine (Pre-fix) that had undergone the formalin treatment prior to the acidic treatment. The results

indicate that when to perform the formalin treatment has influence on the enhancement of the binding capacity of the antibody to the LAH epitope obtained through the acidic treatment of the HA split vaccine, and that the formalin treatment is desirably performed after the acidic treatment. In FIGS. 7 and 8, a vaccine obtained by subjecting the HA split vaccine to the acidic treatment after the formalin treatment in the same manner as described in the above 8 is referred to as "a membrane fusion-type split vaccine (Pre-fix)." Further, according to the procedure of Example 1, a vaccine obtained by subjecting the HA split vaccine to the formalin treatment after the acidic treatment in the same manner as described in Example 1 is referred to as "a membrane fusion-type split vaccine (Post-fix)."

[0072]

As shown in FIG. 8, the titer of the anti-LAH antibody in the sera of the BALB/c mice intraperitoneally inoculated with the membrane fusion-type HA split vaccine was higher than the titer of the anti-LAH antibody in the sera of the BALB/c mice intraperitoneally inoculated with the current HA split vaccine. Furthermore, the membrane fusion-type HA split vaccine (Post-fix) exhibited higher titer of the anti-LAH antibody than the membrane fusion-type split vaccine (Pre-fix).

[0073]

11. Preparation of HA split vaccine

An HA split vaccine is prepared by the method described in the above 1 using particles of H3N2 influenza virus (strain X 31).

[0074]

12. Preliminary Examination of Conditions of Acidic Treatment using Mixing Tank

In an acidic treatment process, pH is adjusted by adding 0.15M citrate buffer (pH 3.5) or dilute hydrochloric acid to phosphate buffered saline. The condition for homogenization after the addition of the citrate buffer is examined by the agitation rate after the addition of the citrate

buffer in a mixing tank to which pH indicator is added and the color change with the elapse of the reaction time. A methyl red pH indicator in 100 mL and 20 L mixing tanks is used, and the color change until 10 minutes after addition at agitation speeds of 100 rpm, 200 rpm, 300 rpm, 400 rpm, and 500 rpm is observed, and recorded in a video.

[0075]

13. Acidic treatment

The HA split vaccine is suspended in phosphate buffered saline, and an acidic treatment is then performed by adding 0.15 M citrate buffer (pH 3.5) or dilute hydrochloric acid to bring 5 conditions of pH (2.0, 3.0, 4.0, 5.0, or 6.0). After standing at 5 temperature conditions (10°C, 25°C, 35°C, 45°C or 55°C) and 3 time conditions (for 10 minutes, 30 minutes, or 1 hour), 1 M Tris buffer (pH 8.0) is added so that the pH is returned to 7.3. Thereafter, centrifugation is performed to obtain a membrane fusion-type HA split vaccine. Formalin is added to the membrane fusion-type HA split vaccine thus prepared to a final concentration of 0.05 v/v%, and left stand for several days.

[0076]

A current HA split vaccine was prepared in the same manner as described in 11 above except that no acidic treatment was provided.

[0077]

14. Binding Capacity of Antibody to LAH Epitope

Binding of anti-LAH monoclonal antibodies (#1 to #5 in FIG. 6) prepared from murine or human peripheral blood infected with strain X31 to the current HA split vaccine or the membrane fusion-type HA split vaccine is measured by ELISA in a similar manner to the above 7, using strain X31 of type H3N2 influenza virus.

INDUSTRIAL APPLICABILITY

[0078]

The present invention is useful for the production of influenza vaccines.

[Sequence Listing Free Text]

[0079]

SEQ ID NO: 1, 2: Synthetic Peptide

[Sequence Listing]

CLAIMS

1. A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method comprising:

subjecting an influenza HA split vaccine, which has not undergone a formalin treatment, to an acidic treatment.

2. A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method comprising:

subjecting an influenza HA split vaccine to an acidic treatment, and

thereafter, subjecting the influenza HA split vaccine to a formalin treatment.

3. A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region, the method comprising:

subjecting an influenza HA split vaccine, which has not undergone a formalin treatment, to an acidic treatment, and

thereafter, subjecting the influenza HA split vaccine to a formalin treatment.

4. A method for producing an influenza HA split vaccine which is capable of producing an antibody that binds to an LAH of an HA stem region and which is effective against an influenza virus that causes antigenic variation, the method comprising:

subjecting an influenza HA split vaccine to an acidic treatment.

5. The method of any one of Claims 1 to 4 wherein the acidic treatment is performed at a pH of 4.4 to 5.8.

6. The method of any one of Claims 1 to 5 wherein the influenza HA split vaccine is of type H3N2 or type H1N1.

7. An influenza HA split vaccine which is effective against an influenza virus that causes antigenic variation, and which is capable of producing an antibody that binds to an LAH of an HA stem region, the vaccine being produced by subjecting an influenza HA split vaccine to an acidic treatment.