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Method of treating viral diseases in animals

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United States Patent [19]

Whitfill et al.

[11] **Patent Number: 6,136,319**

[45] **Date of Patent: *Oct. 24, 2000**

[54] **METHOD OF TREATING VIRAL DISEASES IN ANIMALS**

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[73] Assignee: **The University of Arkansas**, Fayetteville, Ark.

[*] Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

This patent is subject to a terminal disclaimer.

[21] Appl. No.: **09/013,760**

[22] Filed: **Jan. 27, 1998**

Related U.S. Application Data

[63] Continuation of application No. 08/697,268, Aug. 21, 1996, Pat. No. 5,871,748, which is a continuation of application No. 08/345,291, Nov. 28, 1994, abandoned, which is a continuation of application No. 08/008,394, Jan. 25, 1993, Pat. No. 5,397,569, which is a continuation of application No. 07/586,859, Sep. 21, 1990, abandoned, which is a continuation-in-part of application No. 07/480,678, Feb. 15, 1990, abandoned, which is a continuation-in-part of application No. 07/416,035, Oct. 2, 1989, abandoned.

[51] **Int. Cl.**[7] **A61K 39/12**; A61K 39/395; A61K 39/40; A61K 39/42; A61K 39/44

[52] **U.S. Cl.** **424/204.1**; 424/178.1; 424/184.1; 424/187.1; 424/189.1; 424/193.1; 424/196.11; 424/197.11; 424/206.1; 424/207.1; 424/208.1; 424/209.1; 530/380.3; 530/389.4; 530/388.1; 530/388.15

[58] **Field of Search** 424/178.1, 184.1, 424/187.1, 189.1, 193.1, 196.11, 197.11, 204.1, 206.1, 207.1, 208.1, 209.1; 530/388.3, 389.4, 388.1, 388.15

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Primary Examiner—Jeffrey Stucker
Assistant Examiner—Brett Nelson
Attorney, Agent, or Firm—Myers Bigel Sibley & Sajovec

[57] **ABSTRACT**

A method of producing active immunity against a viral disease in an animal subject comprises administering to the subject a vaccine conjugate consisting essentially of a live virus and a neutralizing factor bound to the live virus. The neutralizing factor is selected from the group consisting of antibodies and antibody fragments. The live virus is one capable of producing disease in the subject, and the antibody or antibody fragment is one capable of neutralizing the live virus. Preferred subjects are birds, a preferred virus is Infectious Bursal Disease Virus, and a preferred route of administration to birds is by in ovo administration.

28 Claims, 7 Drawing Sheets

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FIG. 1

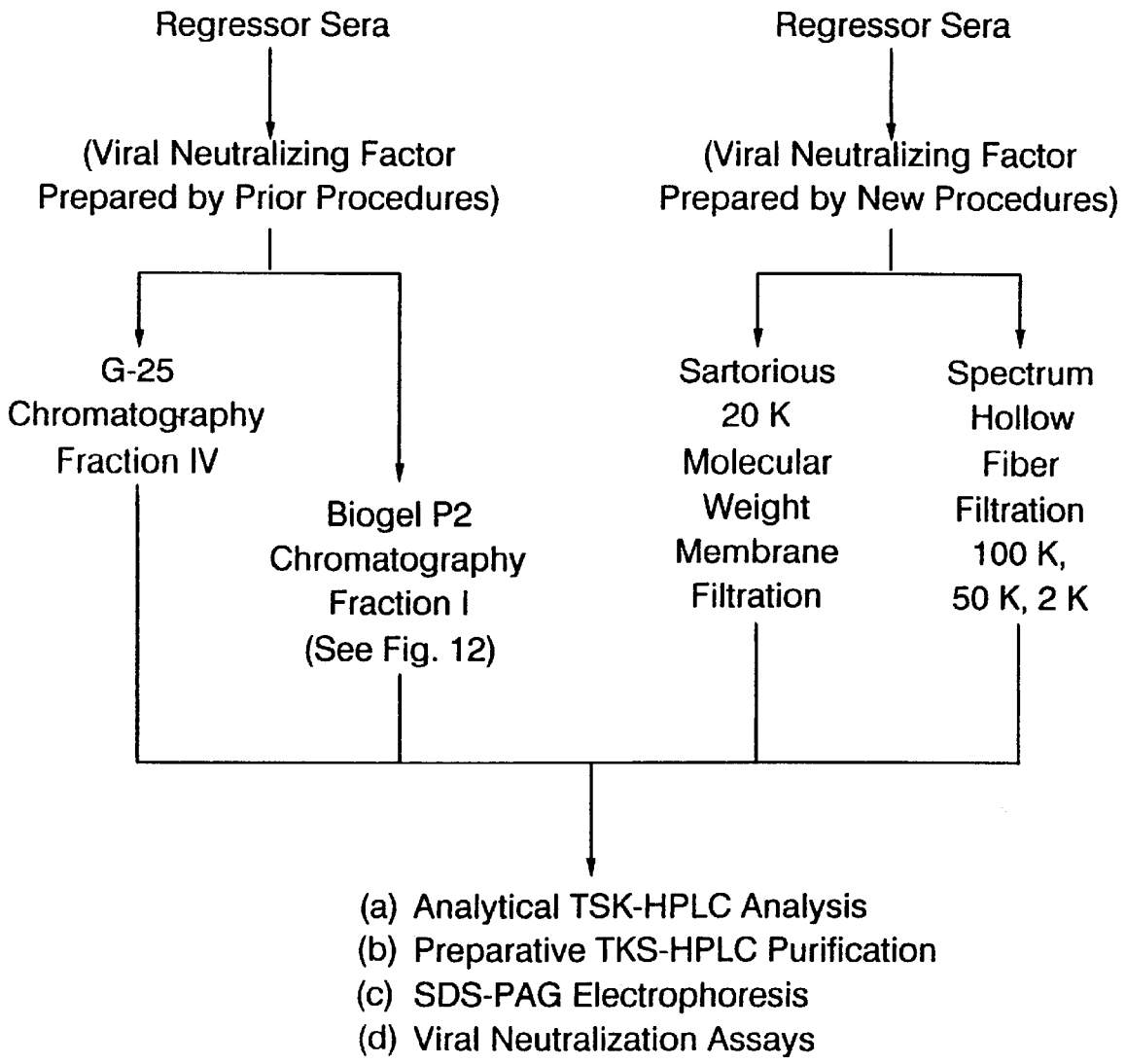

Regressor Sera
(Viral Neutralizing Factor Prepared by Prior Procedures)
Regressor Sera
(Viral Neutralizing Factor Prepared by New Procedures)
G-25 Chromatography Fraction IV
Biogel P2 Chromatography Fraction I (See Fig. 12)
Sartorious 20 K Molecular Weight Membrane Filtration
Spectrum Hollow Fiber Filtration 100 K, 50 K, 2 K
(a) Analytical TSK-HPLC Analysis
(b) Preparative TKS-HPLC Purification
(c) SDS-PAG Electrophoresis
(d) Viral Neutralization Assays

FIG. 2

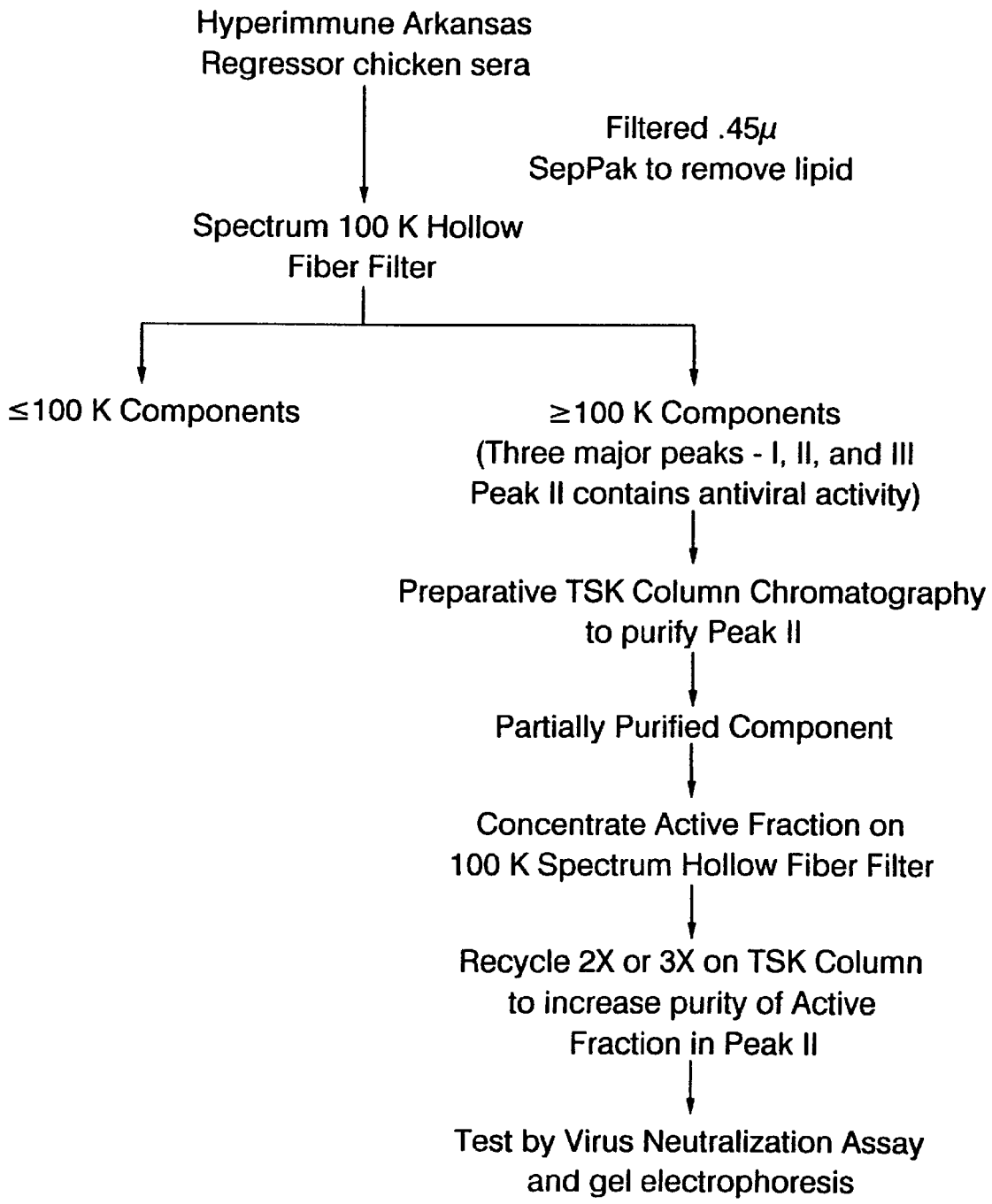

Hyperimmune Arkansas
Regressor chicken sera
Filtered .45μ
SepPak to remove lipid
Spectrum 100 K Hollow
Fiber Filter
≤100 K Components
≥100 K Components
(Three major peaks - I, II, and III
Peak II contains antiviral activity)
Preparative TSK Column Chromatography
to purify Peak II
Partially Purified Component
Concentrate Active Fraction on
100 K Spectrum Hollow Fiber Filter
Recycle 2X or 3X on TSK Column
to increase purity of Active
Fraction in Peak II
Test by Virus Neutralization Assay
and gel electrophoresis

FIG. 3

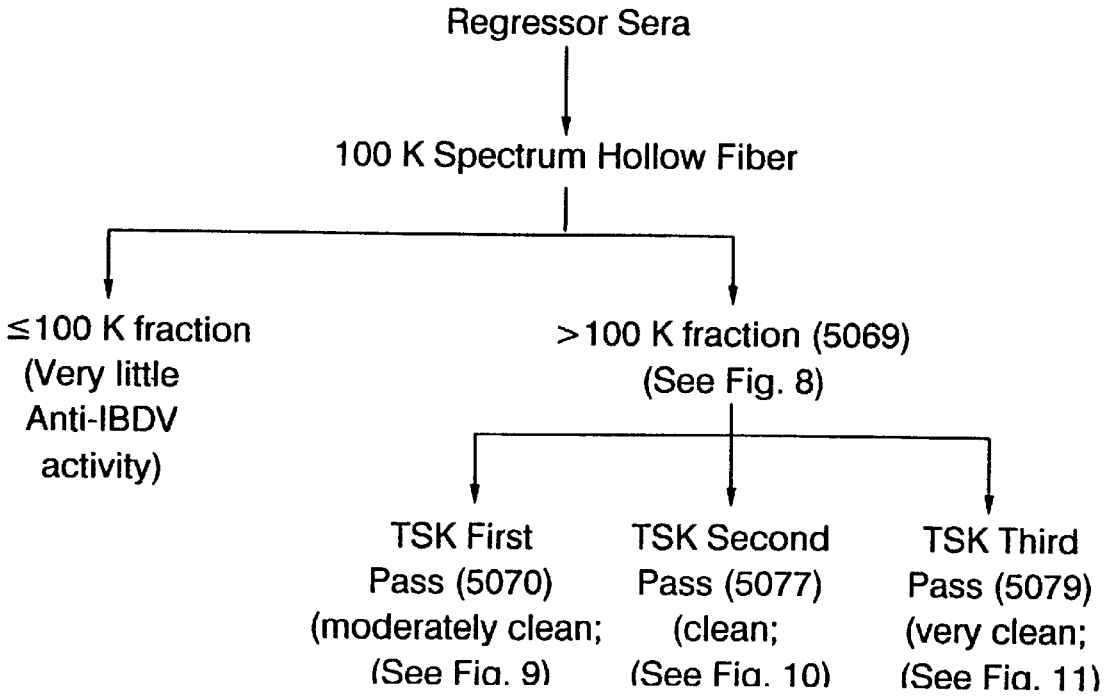
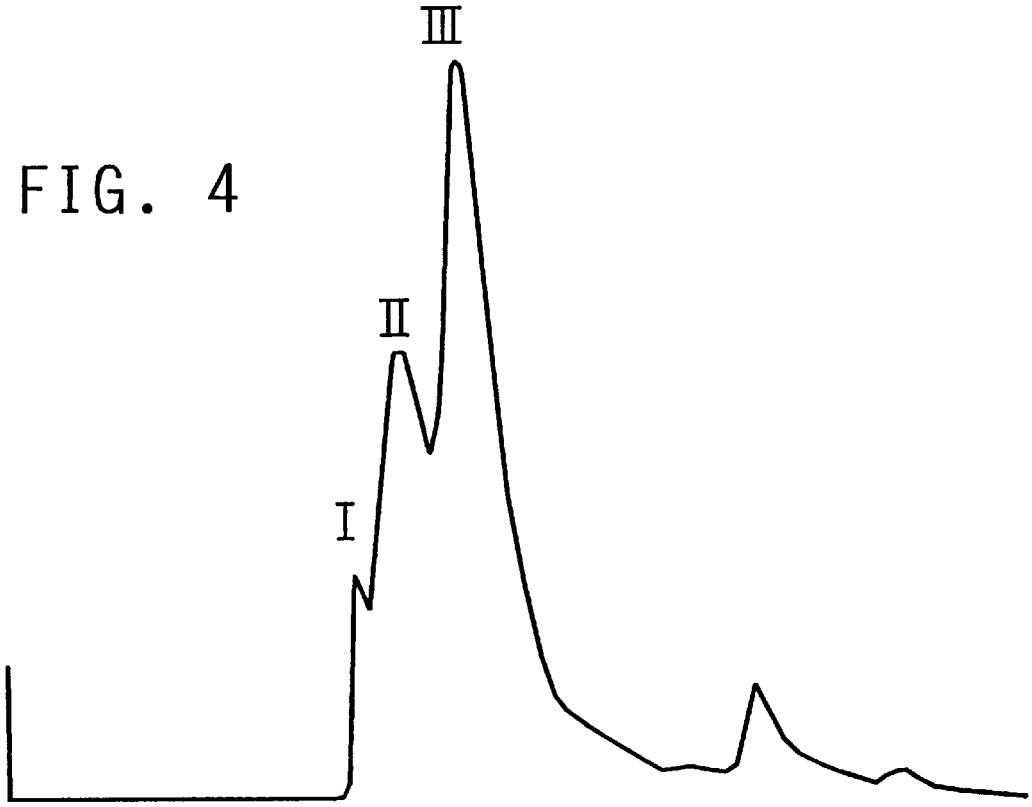
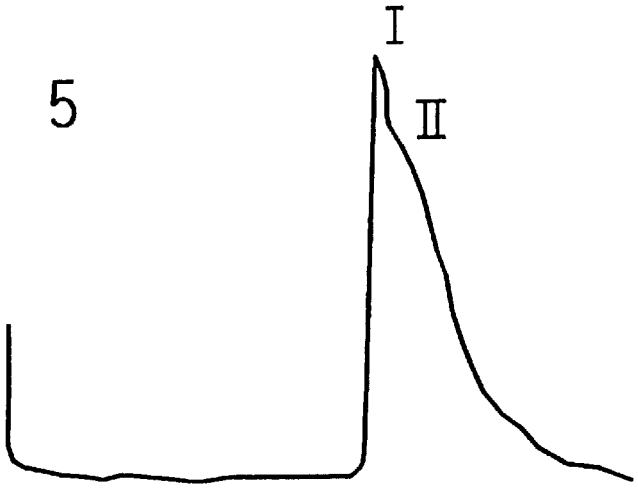

Regressor Sera
100 K Spectrum Hollow Fiber
≤100 K fraction (Very little Anti-IBDV activity)
>100 K fraction (5069) (See Fig. 8)
TSK First Pass (5070) (moderately clean; (See Fig. 9)
TSK Second Pass (5077) (clean; (See Fig. 10)
TSK Third Pass (5079) (very clean; (See Fig. 11)

FIG. 4



Elution Profile of >50K Sera Component of Arkansas Regressor Sera

FIG. 5



Elution Profile of Peak I of Fig. 4

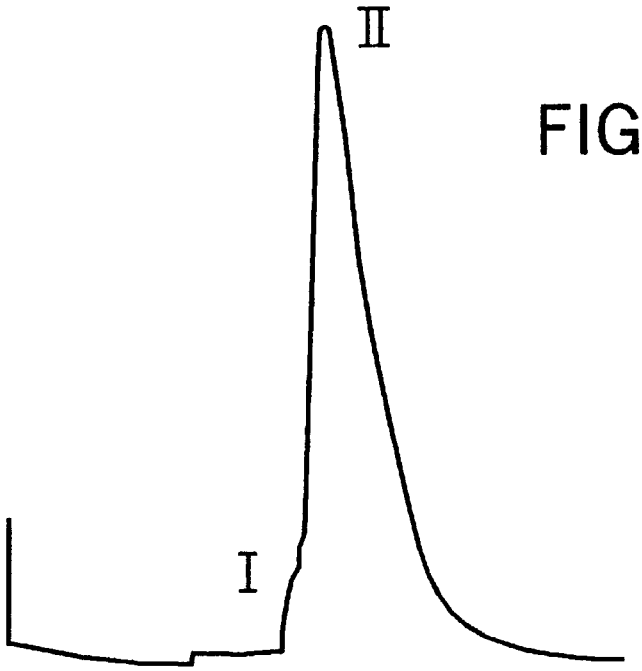


FIG. 6

Elution Profile of Peak II of Fig. 4

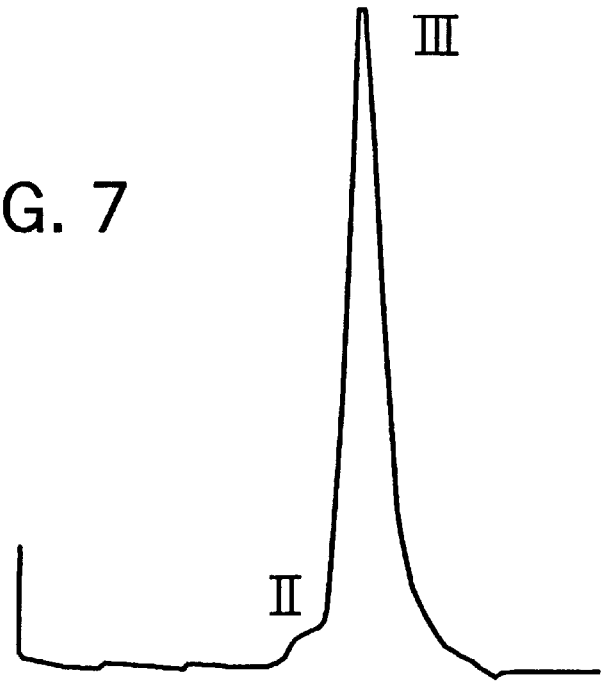
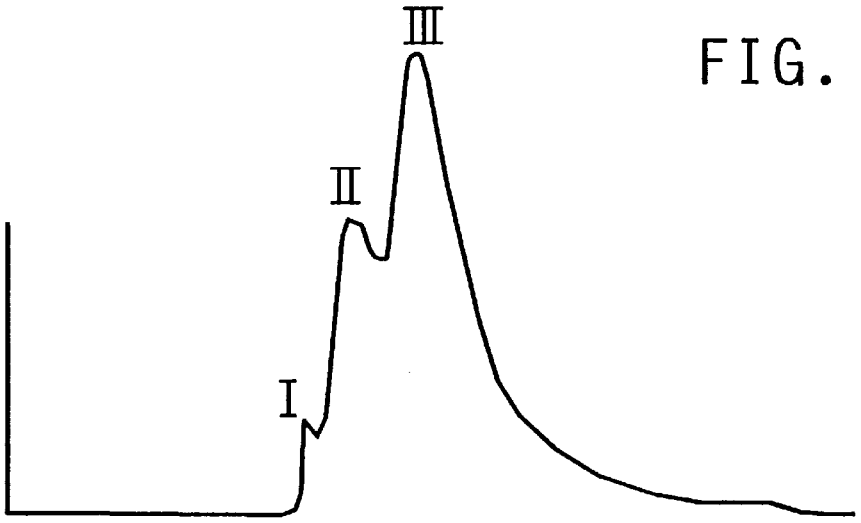


FIG. 7

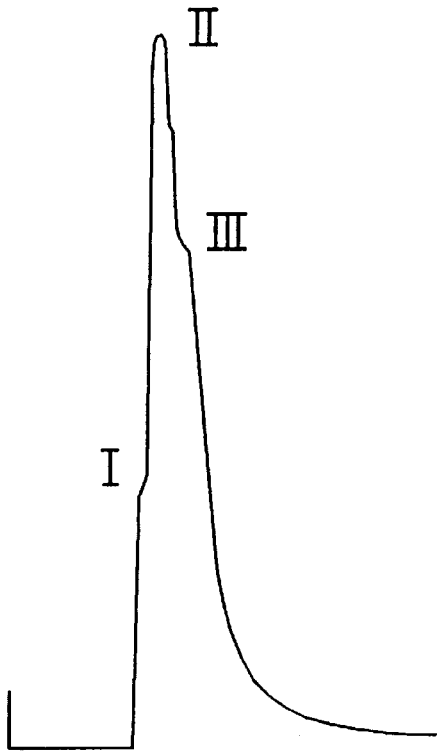
Elution Profile of Peak III of Fig. 4

FIG. 8



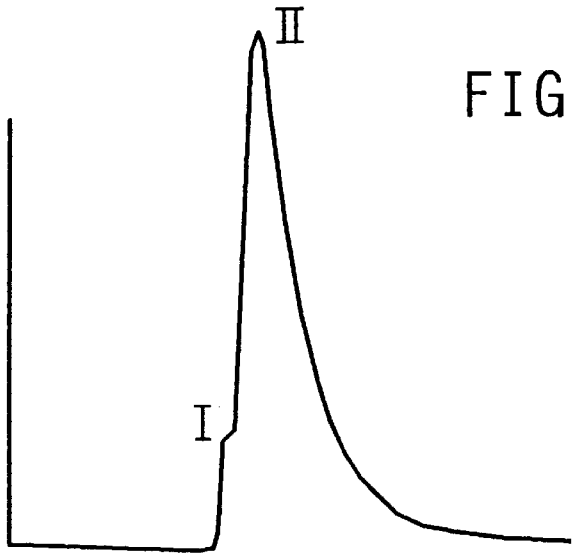
Elution Profile of >100K Sera
Component of Arkansas Regressor Sera

FIG. 9



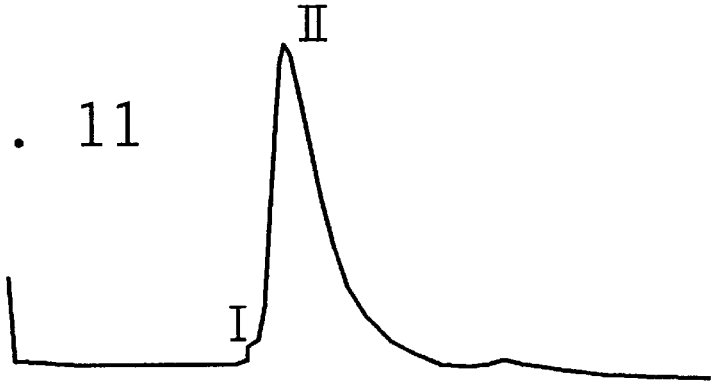
Elution Profile of First Recycling
of Peak II of Fig. 8

FIG. 10



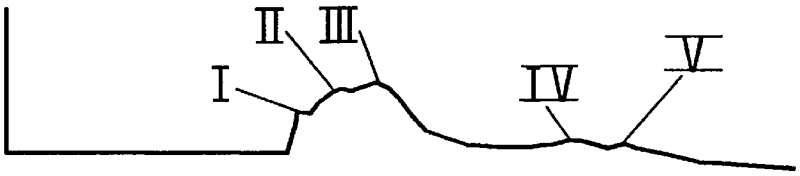
Elution Profile of Second Recycling of Peak II of Fig. 8

FIG. 11



Elution Profile of Third Recycling of Peak II of Fig. 8

FIG. 12



Elution Profile of Prior VNF Preparation

METHOD OF TREATING VIRAL DISEASES IN ANIMALS

RELATED APPLICATIONS

This application is a Continuation of application Ser. No. 08/697,268, filed Aug. 21, 1996, now U.S. Pat. No. 5,871,748, which is a Continuation of application Ser. No. 08/345,291, filed Nov. 28, 1994 (abandoned), which is a Continuation of application Ser. No. 08/008,394, filed Jan. 25, 1993 (issued as U.S. Pat. No. 5,397,569), which is a Continuation of application Ser. No. 07/586,859, filed Sep. 21, 1990, (abandoned), which is a Continuation-in-Part of application Ser. No. 07/480,678, filed Feb. 15, 1990 (abandoned), which is a Continuation-in-Part of application Ser. No. 07/416,035, filed Oct. 2, 1989 (abandoned).

FIELD OF THE INVENTION

The present invention relates to methods of producing active immunity by administering subjects a vaccine conjugate, which conjugate is comprised of a live virus and a neutralizing antibody or fragment thereof.

BACKGROUND OF THE INVENTION

Gyles et al., 47 *Poultry Sci.* 430 (1968), and Gyles and Brown, 50 *Poultry Sci.* 901 (1971), found that regression of Rous sarcoma virus (RSV)-induced tumors is under genetic control in Arkansas progressor line and Arkansas regressor line chickens. Whitfill et al., 61 *Poultry Sci.* 1573 (1982), reported a low molecular weight fraction that was isolated by gel permeation chromatography from Arkansas regressor chicken sera. The active low molecular weight fraction was called the low molecular weight viral neutralizing factor (VNF). See Whitfill et al., 17 *Immunogenetics* 387 (1983).

Gyles and Whitfill, *Annual Report of Project Contributions to NE*-60 (Oct. 1986), subsequently reported that VNF neutralized Rous sarcoma virus and Newcastle's Disease virus when administered in combination therewith to nine day old SPAFAS egg embryos as measured by chorioallantoic membrane pock formation. Later, Gyles and Whitfill, *Annual Report of Project Contributions to NE*-60 (Oct. 1987), reported that VNF neutralized Infectious Bursal Disease Virus (IBDV) and Infectious Bronchitis Virus (IBV) when administered in combination therewith to nine day old SPAFAS egg embryos, and had antimicrobial activity. It has not heretofore been suggested that VNF is a viral neutralizing antibody.

Viral neutralizing antibodies are antibodies which can neutralize the infectivity of a virus if the virus and antibodies are allowed to react together for a sufficient time. Such a procedure is carried out during the course of performing a neutralization test. The neutralization test, which was the first technique used to detect antibodies against virus in serum, can be done with virtually any virus. See generally *Handbook of Experimental Immunology*, 37.9 (D. M. Weir Ed. 2d ed. 1973)(Blackwell Scientific Publications).

N. Phillips, 33 *Vira. Aqr.* (*Lima E. sum.*) 111 (1956) (Summarized in J. Vasington et al., 39 *Poultry Sci.* 1418, 1419 (1960)), in an attempt to confer immediate and lasting immunity against Newcastle Disease Virus in birds, studied the effect of plasma and yolk in combination with live virus. The plasma was obtained from birds that survived a natural outbreak of the disease and the yolk was obtained from eggs produced by the same birds. The results of these studies showed that all chickens receiving simultaneous inoculations of the plasma-yolk mixture and virus, and those which received the virus two days later, survived challenge with artificial inoculation.

J. Vasington et al., 39 *Poultry Sci.* 1418 (1960), investigated the protective value of Newcastle Disease Virus immune serum and gamma globulin against Newcastle Disease virus challenge in 4 to 5 week old chickens. Challenge was carried out simultaneous with or subsequent to administration of the immune serum or gamma globulin. Simultaneous administration of NDV and gamma globulin in one bird was found to protect the bird against death, but did not lead to active immunity. See Id. at 1424 Table 4 and accompanying text. It is not suggested that the virus and antibody be administered as a complex.

H. Stone and W. Boney, 128 *P.S.E.B. Med.* 525 (1968), report the vaccination of 1–2 day old chicks against Newcastle Disease Virus with a vaccine containing chemically inactivated virus antigen in the form of antigen-antibody complexes, free homologous antibody, and an aluminum hydroxide adjuvant. The complexing of the antigen with the inactivated virus did not lead to increased protection against challenge, see Id. at 528, and the data indicated that the use of an adjuvant was critical to the results.

D. Higgins, 14 *Avian Diseases* 579, 585 (1970), notes that the presence of maternal neutralizing antibodies in the yolk of eggs from hens immune to Newcastle's Disease Virus (NDV) is well known. Higgins suggests that, if the antibody-antigen complex formed after yolk sac inoculation of NDV diffuses throughout the embryonic tissues prior to hatching, as do uncombined yolk sac antibodies, and persists in the neonatal chick, it may later stimulate active anti-NDV immunity. Higgins does not suggest that neutralizing antibodies be complexed with a live virus to attenuate that virus, and the complex then administered as a vaccine.

Platt et al., U.S. Pat. No. 4,493,825, disclose a vaccine complex comprised of an immunizing agent with an antibody bound thereto, the antibody in turn having a microparticle bound thereto. Pathogenic microorganisms, whole virus, and antigenic proteins are suggested as immunizing agents. The authors state that the ability to use such complexes as vaccines is surprising, because the immunizing activity of the antigenic protein would have been thought to have been interfered with by the antibody binding. See Col. 2, lines 14–17 therein. The authors do not suggest that their vaccine would be operable without the inclusion of the microparticle, do not suggest that neutralizing antibodies be used, do not suggest that live virus capable of causing disease (i.e., pathogenic) be used, do not suggest that the conjugation of an antibody to a live virus will protect a subject against infection by that live virus, and do not suggest that a neutralizing antibody should be used to obtain protection against infection by a pathogenic live virus when a pathogenic live virus is used as the immunizing agent.

K. Fahey et al., 70 *J. Gen. Virol.* (1989), disclose a viral neutralizing antibody to IBDV. The antibody, which was monoclonal in origin, was used to separate a structural protein from solubilized viral particles for the purpose of developing a subunit vaccine for IBDV. It is not suggested that the viral neutralizing antibody would protect a subject against IBDV so that the IBDV, with the neutralizing antibody bound thereto, could be administered as a live vaccine.

SUMMARY OF THE INVENTION

The present invention is based on our ongoing efforts to characterize Viral Neutralizing Factor (VNF). During this research, the active component of prior preparations of VNF was unexpectedly found to be a higher molecular weight

contaminant in these generally lower molecular weight preparations. Specifically, VNF was found to be a viral neutralizing antibody. This finding makes available new uses of viral neutralizing antibodies, and fragments thereof, in the production of live attenuated viral vaccines. In view of the tendency of maternal antibodies in chicks to interfere with the development of active immunity to a live virus challenge, see P. Abdu et al., *Worlds Poultry Science V* 42, 219, (1968); P. Sharma et al., *Zootecnica International*, 51 (June 1989), these results are particularly unexpected.

The present invention accordingly provides a method of producing active immunity against a viral disease in an animal subject, the method comprising administering to the subject a vaccine conjugate comprised of a live virus and a neutralizing factor bound to the live virus. The neutralizing factor is selected from the group consisting of antibodies and antibody fragments. The antibody or antibody fragment is one capable of neutralizing the live virus. The vaccine conjugate is administered in an amount effective to produce an immune response to the live virus in the subject.

Another aspect of the present invention is a vaccine preparation useful for producing active immunity against a viral disease in an animal subject. The vaccine preparation is a pharmaceutically acceptable formulation which comprises a vaccine conjugate. The vaccine conjugate comprises a live virus and a neutralizing factor bound to the live virus. The neutralizing factor is selected from the group consisting of antibodies and antibody fragments. The antibody or antibody fragment is capable of neutralizing the live virus. The vaccine conjugate is included in the pharmaceutically acceptable formulation in an amount effective to produce an immune response to the live virus in the subject.

Another aspect of the present invention is an article of manufacture comprising a closed, pathogen-impermeable, container and a sterile vaccine formulation as described above enclosed within the container.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**, **2**, and **3** schematically illustrate the various preparations from Arkansas regressor line chicken sera that have been used for the purification of VNF and the determination of relative VNF activities.

FIG. **4** illustrates the elution profile of the ≧50k sera component of Arkansas regressor line chicken sera by TSK chromatography.

FIG. **5** illustrates, by TSK™ chromatography, the elution profile of the peak I component shown in FIG. **4**.

FIG. **6** illustrates the elution profile, by TSK chromatography, of the peak II component shown in FIG. **4**.

FIG. **7** illustrates the elution profile, by TSK chromatography, of the peak III component shown in FIG. **4**.

FIG. **8** illustrates the elution profile of the ≧100k sera component of Arkansas regressor line chicken sera by TSK™ chromatography.

FIGS. **9** through **11** illustrate the increased purification of VNF achieved by first, second, and third recyclings of the peak II component illustrated in FIG. **8** through a TSK™ chromatography column.

FIG. **12** illustrates, by TSK™ chromatography, the purity of VNF prepared by prior techniques.

DETAILED DESCRIPTION OF THE INVENTION

Antibodies used in practicing the present invention are viral neutralizing antibodies. Viral neutralizing antibodies are those which combat the infectivity of a virus in vitro if the virus and the antibodies are allowed to react together for a sufficient time. The source of the viral neutralizing antibody is not critical. They may originate from any animal, including birds (e.g., chicken, turkey) and mammals (e.g., rat, rabbit, goat, horse). The viral neutralizing antibodies may be polyclonal or monoclonal in origin. See, e.g., D. Yelton and M. Scharff, 68 *American Scientist* 510 (1980). The antibodies may be chimeric. See, e.q., M. Walker et al., 26 *Molecular Immunology* 403 (1989). The antibodies may be of the type heretofore known as Viral Neutralizing Factor (VNF). See, e.g., Gyles and Whitfill, supra. VNF used for practicing the present invention may be obtained from the Giant Jungle Fowl (*Gallus gallus*) and strains of birds derived from *Gallus gallus* which are capable of producing VNF. Exemplary of such derivative strains is the Arkansas regressor chicken line. Among other means, stocks of birds can be located through the *International Registry of Poultry Genetics Stocks*, Bulletin No. 476, Agriculture Publication No. U-351376 (available from the University of Connecticut, Storrs, Conn.).

Viral neutralizing antibodies used in practicing the present invention may be immunoglobulins of any isotype, including IgM, IgG, IgA, IgD, and IgE immunoglobulins. IgG and IgM are more preferred, and IgG immunoglobulins (e.g., IgG1, IgG2, Ig,G3, IgG4) are most preferred.

Antibody fragments used in practicing the present invention are fragments of viral neutralizing antibodies which retain the variable region binding site thereof. Exemplary are $F(ab')_2$ fragments, F(ab') fragments, and Fab fragments. See generally Immunology: Basic Processes, 95–97 (J. Bellanti Ed. 2d ed. 1985).

Antibodies or antibody fragments used in practicing the present invention may have additional elements joined thereto. For example, a microsphere or microparticle may be joined to the antibody or antibody fragment, as described in U.S. Pat. No. 4,493,825 to Platt, the disclosure of which is incorporated herein by reference.

The present invention is particularly advantageously employed with viruses which would be pathogenic (i.e., capable of causing disease) in the subject being treated if not for their conjugation to the neutralizing factor. The pathogenicity of the virus may be inherent in the virus itself (e.g., a virus such as Infectious Bursal Disease Virus which is difficult to attenuate) or due to the susceptibility of the subject to be treated (e.g., birds in ovo). In general, many pathogenic viruses have the positive effect of evoking active immunity in subjects infected therewith, and many attenuated vaccine strains of virus have the capability of causing at least some disease in subjects. Hence, the term "pathogenic," as used to describe viruses herein, means that the harm caused to subjects by administration of the virus outweighs any benefit which would result therefrom. It is preferred that the virus be one capable of producing an active immune response thereto in the subject being treated.

The vaccine conjugate is included in the vaccine formulations in an amount per unit dose sufficient to evoke an active immune response to the virus in the subject to be treated. The term "immune response," as used herein, means any level of protection from subsequent exposure to the virus which is of some benefit in a population of subjects, whether in the form of decreased mortality, decreased lesion scores, improved feed conversion ratios, or the reduction of any other detrimental effect of the disease, regardless of whether the protection is partial or complete.

With respect to the degree of protection provided by the neutralizing factor, the quantity of the neutralizing factor

administered in combination with the virus in the vaccine need not be sufficient to provide complete protection from the virus, as long as the detrimental response produced by the virus is reduced to a level at which the benefits of the immune response produced outweigh any harm resulting from the infection. Preferably, with respect to avian subjects administered VNF, birds are administered between about 10 and about 1,000 Activity Units per dose of vaccine conjugate. Pharmaceutical compositions are compounded to include these quantities of VNF per unit dose.

Viruses which may be mixed with the neutralizing factor to form a vaccine include both mammalian and avian viruses. Exemplary of mammalian viruses are the Japanese Encephalitis Virus, Influenza Virus, Sendai Virus, Measles Virus, Human Influenza Virus and Pseudorabies. See, e.g., U.S. Pat. Nos. 4,659,569 and 4,493,825. Exemplary of avian viruses are Rous Sarcoma Virus, Newcastle's Disease Virus, Infectious Bursal Disease Virus, and Infectious Bronchitis Virus.

The term "Infectious Bursal Disease Virus" (IBDV), as used herein, encompasses all strains of IBDV. Exemplary are the Bursal Disease Vaccine, Lukert strain, live virus, which is obtained from either Vineland Laboratories in Vineland, N.J. or Salsbury Laboratories in Charles City, Iowa, the Bursal disease virulent challenge virus, which is obtained from the U.S.D.A. in Ames, Iowa (original isolate from S. A. Edgar), and Infectious Bursal Disease Virus strain VR2161, disclosed in U.S. Pat. No. 4,824,668 to Melchior and Melson.

The term "Rous Sarcoma Virus" (RSV), as used herein, encompasses all strains of RSV. RSV has been comprehensively studied since its discovery early this century. See generally 1 RNA Tumor Viruses: Molecular Biology of Tumor Viruses, Second Edition, 59–61 (R. Weiss, N. Teich, H. Varmus and J. Coffin eds. 1984). An assay technique for Rous Sarcoma Virus is reported at Brit. J. Exptl. Med., 99:183. Moloney, J. Nat. Cancer Inst., 16:877, reports the development of standard lots of the virus for use in quantitative investigations. See also U.S. Pat. No. 3,326,767 to Holper and Kiggins. Numerous Rous sarcoma virus strains are listed in the ATCC Catalogue of Animal and Plant Viruses, Chlamydiae, Rickettsiae and Virus Antisera (5th ed. 1986), at pages 110–112.

The term "Infectious Bronchitis Virus" (IBV), as used herein, encompasses all strains of IBV. Exemplary are Mass. 41 Strain, Arkansas 99 Strain, Connecticut A5968, and Michigan State University Repository Code 42 Strain, all available from American Type Culture Collection, Rockville, Md. The term "Newcastle's Disease Virus" encompasses all strains of Newcastle's Disease Virus.

The term "animals," as used herein, is intended to include, among other things, both mammals and birds. Exemplary mammals include mice, rats, guinea pigs, rabbits, ferrets, dogs, cats, cows, horses and primates including man. The term "bird" is intended to include males or females of any avian species, but is primarily intended to encompass poultry which are commercially raised for eggs or meat. Accordingly, the term "bird" is particularly intended to encompass hens, cocks and drakes of chickens, turkeys, ducks, geese, quail and pheasant. Domestic animals (i.e., non-human animals), are preferred.

Animals may be administered vaccines of the present invention by any suitable means. Exemplary are by oral administration, by intramuscular injection, by subcutaneous injection, by intravenous injection, by intraperitoneal injection, by eye drop or by nasal spray. When the animal to be treated is a bird, the bird may be a hatched bird, including a newly hatched (i.e., about the first three days after hatch), adolescent, and adult birds. Birds may be administered the vaccine in ovo, as described in U.S. Pat. No. 4,458,630 to Sharma (the disclosure of this and all other patent references cited herein is to be incorporated herein by reference).

The in ovo administration of the vaccine involves the administration of the vaccine to eggs. Eggs administered the vaccine of the present invention are fertile eggs which are preferably in the fourth quarter of incubation. Chicken eggs are treated on about the fifteenth to nineteenth day of incubation, and are most preferably treated on about the eighteenth day of incubation (the eighteenth day of embryonic development). Turkey eggs are preferably treated on about the twenty-first to twenty-sixth day of incubation, and are most preferably treated on about the twenty-fifth day of incubation.

Eggs may be administered the vaccine of the invention by any means which transports the compound through the shell. The preferred method of administration is, however, by injection. The site of injection is preferably within either the region defined by the amnion, including the amniotic fluid and the embryo itself, in the yolk sac, or in the air cell. Most preferably, injection is made into the region defined by the amnion. By the beginning of the fourth quarter of incubation, the amnion is sufficiently enlarged that penetration thereof is assured nearly all of the time when the injection is made from the center of the large end of the egg along the longitudinal axis.

The mechanism of egg injection is not critical, but it is preferred that the method not unduly damage the tissues and organs of the embryo or the extraembryonic membranes surrounding it so that the treatment will not decrease hatch rate. A hypodermic syringe fitted with a needle of about 18 to 22 gauge is suitable for the purpose. To inject into the air cell, the needle need only be inserted into the egg by about two millimeters. A one inch needle, when fully inserted from the center of the large end of the egg, will penetrate the shell, the outer and inner shell membranes enclosing the air cell, and the amnion. Depending on the precise stage of development and position of the embryo, a needle of this length will terminate either in the fluid above the chick or in the chick itself. A pilot hole may be punched or drilled through the shell prior to insertion of the needle to prevent damaging or dulling of the needle. If. desired, the egg can be sealed with a substantially bacteria-impermeable sealing material such as wax or the like to prevent subsequent entry of undesirable bacteria.

It is envisioned that a high speed automated egg injection system for avian embryos will be particularly suitable for practicing the present invention. Numerous such devices are available, exemplary being those disclosed in U.S. Pat. No. 4,681,063 to Hebrank and U.S. Pat. Nos. 4,040,388, 4,469,047, and 4,593,646 to Miller. All such devices, as adapted for practicing the present invention, comprise an injector containing the vaccine described herein, with the injector positioned to inject an egg carried by the apparatus with the vaccine. Other features of the apparatus are discussed above. In addition, if desired, a sealing apparatus operatively associated with the injection apparatus may be provided for sealing the hole in the egg after injection thereof.

Preferred egg injection, apparatus for practicing the present invention is disclosed in U.S. Pat. Nos. 4,681,063 and 4,903,635 to Hebrank, the disclosures of which are incorporated herein by reference. This device comprises an injection apparatus for delivering fluid substances into a

plurality of eggs and suction apparatus which simultaneously engages and lifts a plurality of individual eggs from their upwardly facing portions and cooperates with the injection means for injecting the eggs while the eggs are engaged by the suction apparatus. The features of this apparatus may be combined with the features of the apparatus described above for practicing the present invention. Preferred subjects for carrying out the present invention are birds.

The method of the present invention is preferably carried out on birds in ovo. A preferred virus for use in carrying out the present invention is Infectious Bursal Disease Virus.

A vaccine conjugate of the present invention is made by mixing the neutralizing factor with a live virus in a pharmaceutically acceptable carrier for a time sufficient to form a live virus-neutralizing factor conjugate (for example, by combining the neutralizing factor and virus in a common liquid carrier for at least about one hour prior to administration to a subject). This can advantageously be carried out by simply adding hyperimmune sera containing VNF to an aqueous solution containing the live virus. Vaccine formulations of the present invention preferably comprise the vaccine conjugate in lyophilized form or the vaccine conjugate in a pharmaceutically acceptable carrier. Pharmaceutically acceptable carriers are preferably liquid, particularly aqueous, carriers. For the purpose of preparing such vaccine formulations, the neutralizing factor and virus may be mixed in sodium phosphate-buffered saline (pH 7.4) or conventional media such as MEM. The vaccine formulation may be stored in a sterile glass container sealed with a rubber stopper through which liquids may be injected and formulation withdrawn by syringe.

Vaccine formulations of the present invention may optionally contain one or more adjuvants. Any suitable adjuvant can be used, including chemical and polypeptide immunostimulants which enhance the immune system's response to antigens. Preferably, adjuvants such as aluminum hydroxide, aluminum phosphate, plant and animal oils, and the like are administered with the vaccine conjugate in an amount sufficient to enhance the immune response of the subject to the vaccine conjugate. The amount of adjuvant added to the vaccine conjugate will vary depending on the nature of the adjuvant, generally ranging from about 0.1 to about 100 times the weight of the virus, preferably from about 1 to about 10 times the weight of the virus.

The vaccine formulations of the present invention may optionally contain one or more stabilizer. Any suitable stabilizer can be used, including carbohydrates such as sorbitol, manitol, starch, sucrose, dextrin, or glucose; proteins such as albumin or casein; and buffers such as alkaline metal phosphate and the like. The use of a stabilizer is particularly advantageous when the vaccine formulation is a lyophilized formulation.

A preferred embodiment of the present invention provides a method of producing active immunity against Infectious Bursal Disease Virus in an avian subject by administering to the subject, at a time ranging between about the last quarter of in ovo incubation and about the first three days after hatch, a vaccine conjugate comprising live infectious bursal disease virus and a neutralizing factor bound to the live virus. The neutralizing factor is preferably selected from the group consisting of IgG immunoglobulins and IgG immunoglobulin fragments, and is capable of neutralizing the live virus. The vaccine conjugate is administered in an amount effective to produce active immunity against infectious bursal disease virus in said subject. In a specific example, hyperimmune serum from chickens prepared against infectious bursal disease virus is mixed in the proportions described in the following Examples to form a conjugate (e.g., 22 EID_{50}s of virus with 136 Units per 50 μL hyperimmune serum; 2.2 EID_{50}s of virus with 338 Units per μL hyperimmune serum). The virus is IBD-BLEN™ infectious bursal disease virus vaccine available from Sanofi Animal Health, Berlin, Md., USA, Tel. (301) 641–2060. The conjugate is then lyophylized to dryness as a final vaccine product in a vial and stored. For use, the vaccine conjugate is redissolved in diluent and 100 microliters per dose is injected subcutaneously into the neck of the chicken at during normal post-hatch processing (usually day 1 or 2 after hatch).

Another exemplary embodiment of the present invention provides a method of producing active immunity, against Newcastle's Disease Virus in an avian subject by administering to the subject, at a time ranging between about the last quarter of in ovo incubation and about the first three days after hatch, a vaccine conjugate comprising live Newcastle's disease virus and a neutralizing factor bound to the live virus. The neutralizing factor is preferably selected from the group consisting of IgG immunoglobulins and IgG immunoglobulin fragments, and is capable of neutralizing the live virus. The vaccine conjugate is administered in an amount effective to produce active immunity against Newcastle's disease virus in the subject.

The present invention is described in greater detail in the following Examples. These examples are provided for illustrative purposes only, and are not to be taken as limiting.

EXAMPLE 1

Experimental Animals

The birds used for challenge with Rous sarcoma virus and subsequent sera collection were of the Arkansas regressor chicken line and the Arkansas progressor chicken line described in Gyles et al., 46 *Poultry Sci.* 465 (1967), flocks of which are maintained at the Agricultural Research Farm of the University of Arkansas, Fayetteville, Ark., 72701.

EXAMPLE 2

Standard Inoculum of Rous Sarcoma Virus

A standard inoculum of RSV-RAV-1 to be used to stimulate the production of antiviral factor in regressor chicken sera was prepared with an RSV-RAV-1 Bryan High Titer Strain identified as Lot #1 prepared for American Type Culture Collection in Rockville, Md. by Dr. John P. Bader, NCI, NIH. The titer was 2×10^6 PFU per milliliter and was stored at −70° C. before use. Inoculation of birds was accomplished by infecting a standard inoculum of 0.1 milliliter of diluted RSV-RAV-1 into the left wing web as described in Whitfill et al., 61 *Poultry Sci.* 1573 (1981).

COMPARATIVE EXAMPLE A

Preparation of Regressor Chicken Hyperimmune Sera

The object of this example is to demonstrate for comparative purposes prior procedures for preparing tumor homogenate from susceptible chickens to be used to boost regressor chickens to induce production of viral neutralizing factor from hyperimmune sera. Regressor chickens were challenged with a standard inoculum of RSV, and after complete tumor regression as measured by visible disap-

pearance of tumors, were injected once weekly for at least three weeks with a standard inoculum of Rous sarcoma tumor homogenate (RSTH) booster. Five days after the last booster RSTH injection, 20 milliliters of blood was removed from each chicken by cardiac puncture and allowed to clot for one hour at room temperature. Clotted blood was sedimented at 3000×g at room temperature in a Sorvall centrifuge for ten minutes and hyperimmune sera was removed and stored at 5 degrees Celsius. This routine was continued for several weeks on a given group of donor regressor chickens.

COMPARATIVE EXAMPLE B

Preliminary Purification of Low Molecular Weight Antiviral Factor (LMF)

The object of this example is to demonstrate for comparative purposes prior techniques for partially purifying viral neutralizing factor from a large volume of hyperimmune regressor chicken sera. Approximately 400 milliliters of regressor chicken hyperimmune sera prepared according to Comparative Example A above was applied to a SEPHADEX G-25™ fine column (8×35 centimeters) and eluted at 250 milliliters per hour with 0.005M sodium phosphate buffer, pH 7.0. Four peaks were eluted from the column and peak IV, the last to elute at 2800 milliliters, contained the VNF activity against RSV-RAV-1. Peak IV was shown to neutralize RSV-RAV-1 by incubation with the virus with subsequent injection into wing-webs of susceptible chickens, as previously described for SEPHADEX G-100™ fraction II. See Whitfill et al., 61 *Poultry Sci.* 1573 (1981). Peak IV typically eluted in a total volume of 1000 milliliters of buffer at 28 milliliters per tube and was freeze dried and redissolved at a concentration of 100 milligrams per milliliter in sterile distilled water.

COMPARATIVE EXAMPLE C

Further Purification of SEPHADEX G-25™ Peak IV Utilizing BIOGEL P-2™ Column Chromatography

The object of this Example is to demonstrate for comparative purposes prior techniques for the further purification and desalting of viral neutralizing factor from earlier preliminary active fractions utilizing gel filtration column chromatography.

Approximately 35 milliliters of redissolved SEPHADEX G-25™ peak IV (3500 milligrams) obtained as described in Comparative Example B above was applied to a BIOGEL P-2™ column (5 centimeters×40 centimeters), and eluted in distilled water at a flow rate of 90 milliliters per hour. The antiviral activity was found against RSV-RAV-1 in the first peak (Peak I) eluting at the void volume after 390 milliliters at 14 milliliters per tube. This peak I, eluting in a total volume of 100 milliliters, was freeze dried to dryness and the salt free preparation represented the more highly purified preparation of VNF. Approximately 5–10 milligrams of further purified VNF typically resulted from peak I of the BIOGEL P-2™ column. A stock solution of the VNF in phosphate-buffered saline or distilled water was freshly prepared to a concentration of 5 milligrams per milliliter before testing for activity.

One activity unit for this stock solution is defined as the amount of activity against Rous sarcoma virus in one milliliter of this VNF solution. One milliliter of this solution will completely neutralize 500 standard doses of Rous sarcoma virus. A standard dose of Rous sarcoma virus is defined as that dilution of virus in 100 microliters that will produce an average of 70 pocks on SPF nine day old embryo chorioallantoic membranes by day 16. VNF is not toxic to a preparation of 7×10^4 chicken fibroblasts until a dose level of 0.1 Activity Unit is reached.

EXAMPLE 3

Preparation of Delipidated Regressor Line Hyperimmune Sera

This example demonstrates the currently preferred technique for preparing regressor chicken Hyperimmune Sera. The sera was prepared as described in Comparative Example A above, except that clotted blood was centrifuged at 3000 rpm for 15 minutes to remove particulate matter, and the resulting sera then filtered through a 5 micron, 1.2 micron, and 0.45 micron filter respectively. Finally, the sera is passaged through C18 cartridges to remove the lipid contained in the sera.

EXAMPLE 4

Concentration and Hollow Fiber Filtration of Delipidated Hyperimmune Sera

A schematic overview of the currently preferred procedure for purifying VNF is given in FIGS. **1**, **2**, and **3**. This example gives additional information on the procedures described in these Figures.

A sera prepared as described in example 3 above is circulated through a SPECTRUM™ 50k or 100k hollow fiber breaker (available from Spectrum, Los Angeles, Calif., USA) and concentrated at least 4 fold for the greater than 50,000 molecular weight fraction (≧50k sera component) or the greater than 100,000 molecular weight fraction (≧100k sera component). Either the ≧50k sera or the ≧100k sera component is further fractionated on a preparative TSK™ column in accordance with the procedures described in Example 5 below, with the VNF being contained in the 150k to 180k portion of each sera component.

EXAMPLE 5

Separation of >50k or >100k Sera Components On a Preparative TSK™ Column

A preparative SPHEROGEL TSK 2000 SW™ column measuring 21.5 mm by 60 cm is run in 3× phosphate buffered-saline at a flow rate of 8 ml per minute to separate the ≧50k and ≧100k sera components into the fractions shown in FIG. **4** or FIG. **8**. Peak percentages for FIGS. **4** and **8** are given in Tables 1 and 2 below. Note that the time for the elution for peaks will vary slightly depending on experimental parameters. such as the use of precolumns and slight variations in buffers. By recycling the greater than 50K fractions back through the column, the peaks I, II, or III are partially isolated one from the other. These are shown in FIG. **5** (Peak I of FIG. **4** at 5.89 minutes), FIG. **6** (peak II of FIG. **4** at 6.71 minutes), and FIG. **7** (peak III of FIG. **4** at 7.86 minutes) respectively. The viral neutralizing activity is located only in Peak II as it was shown to contain the greatest amount of specific activity.

TABLE 1

Peak Percentages for FIG. 4			
Peak	Retention Time	Area Percent	Height Percent
I	5.88	4.2%	14.3%
II	6.72	25.7%	27.9%
III	7.79	58.0%	46.3%

TABLE 2

Peak Percentages for FIG. 8			
Peak	Retention Time	Area Percent	Heiqht Percent
I	5.92	2.4%	10.9%
II	7.02	23.6%	34.0%
III	8.39	72.1%	53.1%

FIGS. **8**, **9**, **10**, and **11** show how Peak II of FIG. **8** is further purified by continued recycling through the TSK™ column. This mixture of unpurified ≧100k sera components was initially labelled 5069a, then with further purification, 5070a, 5077a, and finally 5079a, which is the most highly purified form. As shown by the Figures, each time the peak II section eluting from the TSK™ column is cut and recycled, it becomes further purified and the specific activity is increased. The peak percentages for FIG. **11** are given in Table 3 below. Activity Units for the highly purified IgG fraction containing active VNF are calculated as follows. The ED_{50} titer against IBDV is determined using viral neutralization assays as described below. The ED_{50} titer is the dilution of VNF in 50 μl that will protect 50% of the cells from being killed by the virus. Calculations are based on arbitrarily assigning an ED_{50} dilution titer of 1:25 as being equal to 1 Activity Unit. The actual ED_{50} titer for the specific preparation of VNF is then converted to units per milliliter and finally units per microgram which is defined as the specific activity (see Tables 5–7 for examples of this calculation).

TABLE 3

Peak Percentages for FIG. 11			
Peak	Retention Time	Area Percent	Height Percent
I	4.91	.5%	1.0%
II (IqG)	7.01	98.7%	97.1%
IV	12.39	.9%	1.8%

COMPARATIVE EXAMPLE D

Purity of P-2 Peak I From Comparative Example C by TSK™ Chromatography

This Example demonstrates the lack of purity in previous preparations of VNF. A stock solution of VNF prepared as described in Comparative Example C above was applied to a TSK chromatography column as described in Example 5 above. The elution profile is given in FIG. **12**, and the percentages for each peak is given in Table 4 below. Note that the area percent for IgG is only 18.4%. Compare this Table to Table 3.

TABLE 4

Peak Percentages for FIG. 12			
Peak	Retention Time	Area Percent	Height Percent
I (Macroglobulins)	5.55	5.9%	18.9%
II (IgG)	6.26	18.4%	28.2%
III (Albumin)	6.86	44.1%	31.0%
IV (Low Molecular Weight Contaminant)	10.51	14.3%	10.0%
V (Low Molecular Weight Contaminant)	11.41	15.8%	9.8%

EXAMPLE 6

SDS-PAGE of Purified VNF Fractions

SDS-polyacrylamide gel electrophoresis (SDS-PAGE) separations of the most highly purified VNF components obtained in the foregoing Examples conclusively identify VNF as an IgG immunoglobulin.

10 cm by 10 cm gels for SDS-PAGE having a gradient that separates in the 5,000 to 200,000 MW range were obtained from ISS-Enprotech of Hyde Park, Mass., USA. On such gels, Peak II behaves identical to chicken IgG in that it produces 65,000 and 25,000 MW components in the presence of 2-mercaptoethanol (2-ME). On such gels, but without 2-ME, Peak II migrates with a major band at about 180,000 MW, as does chicken IgG.

EXAMPLE 7

Chicken Fibroblast Assay

The chicken fibroblast assay is useful as an in vitro screen for identifying VNF activity. It is useful for confirming the purification of VNF from a known source or confirming the presence of VNF in a perspective source. Our assay is based on standard procedures developed by J. Skeeles et al., 23 Avilan Dis. 95 (1979). See also *Diseases of Poultry*, 574 (M. Hofstad Ed., 8th ed. 1984). In brief, fibroblasts are harvested from 9–11 day old specific pathogen-free embryos, grown to a thin layer in culture dishes on Complete Minimal Essential Media, and transferred to microtiter plate wells containing Infectious Bursal Disease Virus (Lukert's Strain) (IBDV). When desired, the IBDV in the microtiter plate is mixed prior to addition of the fibroblast cells with a preparation containing VNF, or suspected of containing VNF, to determine the presence or absence, or degree of, viral neutralizing activity in the preparation. Incubation of IBDV with a prospective neutralizing preparation is carried out for about one hour at 37° C. We determine the end-point of our assay with a MTT Dye reduction assay. Specific aspects of our procedure are given below.

A. Preparation of Fibroblasts for Use in Microtiter Plates.

1. Harvest and culture fibroblasts.

2. After cells have become confluent, remove the media from the tissue culture dishes (Falcon 150×25 mm) and trypsinize with 15–20 mLs of trypsin. Placing the plates in the incubator for 2–5 minutes after adding the trypsin will help the cells to release from the dish quicker than at room temperature.

3. After the cells have released from the dishes, add 5 mLs of Newborn Calf Serum to neutralize the trypsin. Gently swirl the dishes to thoroughly mix the serum with the trypsin.

4. Pipette the trypsin/serum and cells from the dishes into equal aliquots in 50 mL centrifuge tubes. It is helpful to tilt the plate slightly on the side and to rinse the plate with the trypsin/serum mixture to release any adhering cells. Bring the volume of the tubes up to the 40 mL mark with MEM with 5% FCS to neutralize any remaining trypsin.

5. Spin the mixture in the tubes for 10 minutes at 1500 rpm at 16° C.

6. After spinning, pour off the supernatant and add 10 mLs of MEM with 5% FCS to each tube. Mix the cells with a pipette to break up any clumps. Combine all aliquots into one container and mix well.

7. From the combined aliquot, remove a small portion and prepare a 1:10 or 1:20 dilution in MEM with 5% FCS (a 1 mL+9 mL dilution is usually sufficient to get a representative sample, but a 1 mL+19 mL dilution will reduce the number of cells to count).

8. Count the diluted cells on a hemacytometer and dilute in MEM with 5% FCS to make a 0.5×10^6 cells/mL solution.

9. Add 200 μL of the cell solution to the desired wells of a microtiter plate using a multichannel pipetter. The cell solution must be kept well mixed in order to keep an even dispersal of cells within all the wells. If 15–20 mLs of the cell solution are placed in a sterile petri dish and replenished with freshly mixed cells between each couple of plates, this will help to insure even dispersal of cells into all wells.

B. Incubation of Microtiter Plates.

Incubate microtiter plates for 2 days in a 37° C. incubator with 5.5% CO_2. Plates may be observed under a microscope after 1–2 days for preliminary test results or to check for visible contamination. Contamination may appear as cloudiness or small black specks in the media.

C. MTT Tetrazolium Dye Reduction Assay for Proliferation or Neutralization.

1. Mix a 5 mg/mL solution of MTT tetrazolium dye (obtained from U.S. Biochemical Corp., Cleveland, Ohio) in 1×PBS. Not all of the crystals will dissolve. Filter sterilize through a 0.45 μm syringe filter under a sterile hood.

2. Under a sterile hood, remove 100 μL of liquid from each well in each plate. "Pulse" the plates by adding 20 μL of MTT to each well after the liquid is removed. Return plates to the incubator for 3 hours.

3. After incubation, remove 100 μL of solution from each well of the plate and discard (this step does not have to be sterile).

4. Add 100 μL of Acid Isopropanol (40 mL 1N HCl or 3.3 mL 12 N HCl in 1 liter isopropanol) to each well.

5. Mix on a shaker for 1 minute at medium high speed (position 6 on a Dynatech Shaker).

6. Read OD within 30 minutes using a wavelength of 570 nm.

7. Calibrate to 0 absorbance with medium +MTT.

8. Read with an appropriate software program (i.e., Immunosoft™) and template on a microplate reader.

EXAMPLE 8

Viral Neutralizing Activity of Various Serum Fractions Against Infectious Bursal Disease Virus in the Chicken Fibroblast Assay

The various serum fractions described in Examples 3 to 6 above were tested for activity against IBDV in accordance with the procedures described in Example 7 above. These data are given in Tables 5 and 6 below. Peak II was the only fraction containing the majority of viral neutralizing activity. In all cases, the specific activity was greatest for Peak II and greatest for the most highly purified form of peak II (5079b, peak II—Table 7, or 5079a—Table 8). The relative percentage of active VNF contained in the peak II IgG fraction varies from one serum preparation to another. FIG. **3** and FIGS. **8–11** show the purification scheme and profiles of purifying the IgG fraction containing VNF. Tables 5–7 show the activities of various fractions from the TSK2000 column. Fraction 5079a activity is shown in Table 8. This 5079a fraction was fractionated into 5079b, peak I, which contained very low levels of macroglobulin contaminants, and 5079b, peak II, which contained the IgG fraction. Table 7 shows that 5079b, peak II contains the VNF activity.

TABLE 5

Virus Neutralization Activity of High and Low Molecular Weight Serum Factors Against Infectious Bursal Disease Virus (IBDV)[1,2,3]

Sample #	Origin	Titer ED50	Units/ 50 μl	Units/ ml[4]	Protein (μg/ ml)	Specific Activity (Units/ μg)
5046	≧50K (S)[5]	11,220	448.8	8976	60,350	.1
5*21	Peak I-TSK	22.4	.89	20	123	.2
5*221	Peak II-TSK	25.7	1.02	21	26	.8
5*332	Peak III-TSK	4	.16	3.2	110	.0
5061	≧100K (S)	1,778	71	1422	19,120	.1
5062	≦100K (S)	2	.08	1.6	90	.0
5032	≦20K (Sar)[5]	46.7	1.86	37.3	660	.1

[1]HyVAC chicken fibroblasts at 1×10^5 cells/well in 200 μl volume were used in assay.

[2]Various fractions were tested in 5 fold dilutions through 1:15,625 in 50 μl volumes/well.

[3]Virus used was Leukerts Strain IBDV at 1:100 dilution in 50 μl volume well.

[4]Calculations based on 1:25 dilution = 1 unit af activity in 50 μl volume.

[5]S = SPECTRUM Hollow Fiber, Sar = Sartorious membrane system.

TABLE 6

Virus Neutralization Activity of Various Serum Fractions Against Infectious Bursal Disease Virus (IBDV) With Increased Purification of Active Factor

Sample #	Origin	Titer ED50	Units/ 50 μl	Units/ ml	Protein (μg/ ml)	Specific Activity (Units/ μg)
5069	≧100K K (I, II, III)	17,782	711.3	14,226	90.443	.2
5070	Peaks I, II, III (1st TSK)	4,168	166.7	3,334	12,923	.3
5077	Peak II (2nd TSK)	1,000	40	800	1,073	.7
5075	HMW ≦20K Sartorious	123	4.9	98	255	.4
P2	Comp. Ex. C	60.2	2.4	48	91	.5

TABLE 7

Virus Neutralization Activity of Chicken Sera Fractions at Various Stages of Purification Against Infectious Bursal Disease Virus

Sample #	Origin	Titer ED50	Units/ 50 μl	Units/ ml	Protein (μg/ ml)	Specific Activity (Units/ μg)
5079b (I)	Further purified 5079a into peak I	354	14	280	5,400	.1
5979b (II)	Further purified 5079a into peak II (IgG)	316	12.6	252	350	.7
5069a	(I, II, III) ≧ 100K (S)	16,982	679	13,580	90,443	.2
5070a	I, II, III (1st TSK Prep)	12,589	503	10,060	34,125	.3
5077a	II- (2nd TSK Prep)	5,011	200	4,000	6,720	.6

EXAMPLE 9

Viral Neutralizing Factor Found in Sera From Other Regressor Lines of Chickens with the Chicken Fibroblast Assay

These experiments were carried out in essentially the same manner as the experiments described in Example 8 above, except that alternate sources for Viral Neutralizing Factor were tested. The data for these experiments are given in Table 8 below. Table 8 also compares the regressor sera with HyLine sera. These data indicate that sera from the East Lansing regressor lines of chickens tested do not contain significant VNF activity. In addition, it was found that Sera from unchallenged Arkansas Regressor birds contains VNF, and that sera from challenged Arkansas Progressor chickens contains VNF-like activity comparable to challenged Arkansas Regressor chickens.

TABLE 8

Virus Neutralization Activity of Chicken Sera From Various Genetically Different Lines of Chickens Against Infectious Bursal Disease Virus

Sample #	Origin	Titer ED50	Units/ 50 μl	Units/ ml	Protein (μg/ ml)	Specific Activity (Units/ μg)
5079a	Control Peak	625	25	500	650	.8
Progressor sera #4565	ARK Challenged	3,548	142	2,838		

TABLE 8-continued

Virus Neutralization Activity of Chicken Sera From Various Genetically Different Lines of Chickens Against Infectious Bursal Disease Virus

Sample #	Origin	Titer ED50	Units/ 50 μl	Units/ ml	Protein (μg/ ml)	Specific Activity (Units/ μg)
Progressor sera #676	ARK Unchallenged	20	0.8	16		
Regressor sera #194	ARK Unchallenged	1,258	50	1,000		
Regressor sera	(Challenged-Boost)	3,162	126.4	2,528	27,430	.1
HyLine sera	(Challenged RSV 1st)	1	.04	.8	24,250	
East Lansing 12733	15.C-12xC	0	0	0		
East Lansing 13133	15.Cx12	0	0	0		
East Lansing 12772	6.3 × 15.6	35	1.4	28		
East Lansing 12760	6.3	0	0	0		
East Lansing 12792	15.6 × 2	0	0	0		

EXAMPLE 10

Protection of Chicks at Hatch from Live Virus Administered In Ovo with VNF

This experiment demonstrates that VNF protects chickens at hatch from IBDV given as a vaccine in ovo at day 18 of incubation. Note that existing vaccine strains of IBDV are so infectious that they are difficult to use in ovo without severe reductions in hatchability.

The procedure described herein also provides a test for conjugates capable of serving as a vaccine.

The study consisted of 9 groups with 10–15 HYVAC embryonated eggs in each group. Standard vaccine against IBDV was provided by CEVA Laboratories, IBD-BLEN™ (1000 doses/vial). Doses of 10×, 1×, 0.1×, and 0.01× of vaccine per 50 μl volume were prepared. VNF was used at 800 μg/50 μl volume as a 1× dose and doses of VNF were prepared in 1× (800 μg) and 0.1× dose (80 μg)/50 μl amounts. For in ovo injection 50 μl IBD-BLEN™ and 50 μl VNF were mixed and made up to 200 μl total volume using CEVA diluent. Various doses of IBD-BLEN™ plus VNF were administered as vaccines, and various doses of IBD-BLEN™ vaccine alone were used to vaccinate the 18 day old embryos. Table 9 lists the vaccine treatments that the various groups received. The birds were allowed to hatch and were grown out in separate groups to day 5 post hatch. At this time the birds were weighed and the bursas weighed and examined.

Nine groups of bursas, three per group, were submitted for histological evaluation. These tissues were graded in the following manner: 0=normal; 1=minimal change (which includes slight irregularity to the surface mucosa, some

depletion of lymphocytes in some follicles with the normal size); 2=mild changes—mild invaginations, with some depletion of lymphocytes and some atrophy of the follicles (this will also include some inflammatory changes with no necrosis); 3=moderate changes—more extensive invagination of the mucosa with the folds being reduced in size (most follicles will be atrophic and/or depleted or lymphocytes, more extensive inflammation or necrosis); 4=extensive changes—folds obviously atrophied (inter-follicular epithelium will be depressed in the folds causing some vacuole-like formation. This will include no normal follicles with more extensive inflammation or necrosis); 5=severe—normal architecture is severely disrupted, folds markedly reduced in size. This may also include extensive inflammation or necrosis.

Tables 9 and 10 show the body weight gains, percentage of hatch, bursal weight, and bursa histology among various groups. Birds receiving the 10× dose IBD-BLEN™+1× dose VNF showed significantly greater hatchability (100%) than those receiving the 10X dose of IBD-BLEN™ alone (55%). The same was true at the 1× vaccine dose level. Body weight gain was decreased (5 to 9 grams) in birds receiving the 1×, 0.1×, and 0.01× IBD-BLEN™ vaccine dose alone (Table 11) when compared to uninoculated controls (14.8 grams). However, when VNF was added to these same doses of IBD-BLEN™, the body weight gain was significantly increased (17 to 18 grams).

Essentially the same effect was seen on bursa weight as on body weight gain. The IBD-BLEN™ doses alone produced bursal atrophy and bursa weight loss (0.04 to .0.06 gram) by day 5 when compared to controls (0.13 gram). The addition of VNF with vaccine resulted in bursas with normal weight (0.12 to 0.15 gram) (Table 10). However, the bursal histology showed that a ratio in the vaccine of 1× virus to 10× VNF was required to more completely protect the bursa from IBDV infection. A 1× virus to 1× VNF ratio with vaccine protected hatchability, body weight gain, and bursal weight, but did not prevent some un-neutralized virus from causing bursal lymphocyte depletion (Table 10).

TABLE 9

InOvo Vaccination with IBD-BLEN ™ and VNF and Effect on Hatchability and Body Weight Gain from Day 0 to Day 5

	Mean Body Weight (g)	SEM	n	% Hatch
PERCENT HATCH AND BODY WEIGHT GAIN FROM DAY 0 TO DAY 5				
IBD-BLEN ™ 10X[1]	.	.	1	55
IBM-BLEN ™ 10X + VNF-1(1X)2	11.39^{BC}	1.91	11	100
IBD-BLEN ™ 1X	5.01^{D}	2.55	10	83
IB-BLEN ™ 1X + VNF-1(1X)	18.33^{A}	1.49	11	92
IBD-BLEN ™ .1X	7.70^{CD}	1.53	9	91
IBD-BLEN ™ .1X + VNF-2 (.1X)	16.43^{A}	1.64	10	91
IBD-BLEN ™ .01X	8.99^{CD}	1.26	10	91
IBD-BLEN ™ .01X + VNF-2 (.1X)	17.52^{A}	1.50	10	100
Positive Control (No Vaccination)	14.80^{AB}	1.21	11	100

Treatment was significant at the .05 level for groups with different superscripts.
[1]A 1X dose of IBD-BLEN ™ represents an ED_{50} titer value of 1:500.
[2]A 1X dose of VNF represents 800 μg/dose.

TABLE 10

In Ovo Vaccination with IBD-BLEN ™ and VNF and Effect on Bursa Weight and Histology

	Mean Bursal Weight (g)	SEM	n	Bursa Histology Scores
IBD-BLEN ™ 10X	.	.	1	3, 3
IBM-BLEN ™ 10X + VNF-1(1X)	$.07^{B}$	.01	11	3, 3, 3
IBD-BLEN ™ 1X	$.04^{B}$	.00	10	3, 4, 4
IBD-BLEN ™ 1X + VNF-1 (1X)	$.12^{A}$	.02	11	3, 3, 3
IBD BLEN ™ .1X	$.06^{B}$	.00	9	3, 4, 3
IBD-BLEN ™ .1X + VNF-2 (.1X)	$.11^{A}$	.01	10	3, 3, 4
IBD-BLEN ™ .01X	$.06^{B}$	.01	6	3, 3, 5
IBD-BLEN ™ .01X + VNF-2 (.1X)	$.15^{A}$	.02	6	0, 0, 2
Positive Control	$.13^{A}$	.01	8	0, 0, 1

Treatment was significant at the .05 level for groups with different superscripts.

EXAMPLE 11

Immunization of Chicks by Administration of VNF and Live Virus In Ovo

This Example extends Example 10 above by demonstrating that a VNF-IBDV conjugate actually immunizes chickens against Infectious Bursal Disease Virus (IBDV). In this experiment, VNF was preincubated with CEVA IBD-BLEN™ vaccine, the vaccine provided at recommended and less than optimal concentrations, and the mixture administered in ovo to embryonated eggs prior to live challenge with USDA-IBDV at day 39 post vaccination (or day 35 post hatch).

The study consisted of ten groups. HYVAC eggs were used in Groups 1–6 and SPAFAS eggs were used in Groups 7–10. Each group was housed in a separate isolation unit and all units were located in the same room. Treatments differed by materials being administered and by methods of administration. Treatment groups, doses, and sample sizes are given in Table 11 below.

Baseline data was collected from positive control groups (Groups 1 and 7), and from negative control groups (Groups 2 and 8). Fertile, viable SPAFAS-SPF and HYVAC eggs were vaccinated by in ovo manual injection on Day 18 of incubation. Injection was through the top of the egg into the amnion. The volume of injection was 200 μl. Parameters measured were hatchability, hatch weight, IBD antibody titer, body weight, bursa weight, and bursa histology.

TABLE 11

Treatment Groups, Doses, and Sample Sizes

Group No.	Treatment Description	CEVA Vaccine Dose In Ovo	USDA-IBDV Dose (PFU) Day 35 Post Hatch	VNF Dose (μg)	Est. # of Eggs
HYVAC EGGS					
1	Positive Control		47		21

TABLE 11-continued

Treatment Groups, Doses, and Sample Sizes

Group No.	Treatment Description	CEVA Vaccine Dose In Ovo	USDA-IBDV Dose (PFU) Day 35 Post Hatch	VNF Dose (μg)	Est. # of Eggs
2	Negative Control IBD-BLEN ™ Vaccine (1X)[1]	1X	47		38
3	IBD-BLEN ™ (1X) + VNF (Dose 1)2	1X	47	800	22
4	IBD-BLEN ™ (1X) + VNF (Dose 2)	1X	47	80	22
5	IBD-BLEN ™ (1X) + VNF (Dose 3)	1X	47	8	38
6	VNF Alone (Dose 1)		47		21
SPAFAS EGGS					
7	Positive Control		47		25
8	Negative Control IBD-BLEN ™ Vaccine (.1X)	.1X	47		25
9	IBD-BLEN ™ (.1X) + VNF (Dose 1)	.1X	47	860	25
10	IBD-BLEN ™ (.1X) + VNF (Dose 2)	.1X	47	80	25

[1]A 1X dose (or standard dose) of IBD-BLEN ™ represents an ED_{50} titer value of 1:500.
[2]VNF dose 1 = 1 standard VNF dose (800 μg/dose), VNF dose 2 = .1X standard VNF dose, and VNF dose 3 = .01X standard VNF dose.

The results of this experiment are illustrated in Tables 12 to 15 below. HYVAC birds that received VNF mixed with IBD-BLEN™ demonstrated increased hatchability (82%) as compared to those that received vaccine alone (32%), and better hatchability was seen at the higher concentrations of VNF (82–47%) (Table 12). The SPAFAS hatchability cannot be compared (Table 12) due to other problems encountered during hatch. However, those remaining alive for the rest of the study represent reliable birds for examination of study parameters. Mortality to day 35 was greater in those groups receiving vaccine alone or in vaccine combination with the lower doses of VNF (Table 12). Higher doses of VNF protected against high mortality when mixed with the vaccine (data was similar to controls).

HYVAC birds that received VNF mixed with IBD-BLEN™ showed normal weight gain (45–59 grams) after challenge with USDA-IBDV but the nonvaccinated birds showed low weight gain (5.6 grams) (Table 13). Vaccination with VNF alone did not offer protection against the USDA challenge. Also, mortality for these groups was reduced when compared to unvaccinated controls (Table 12).

In general, a higher VNF to virus ratio offered increased protection to the bursa after USDA challenge (Table 14). Control bursas receiving no vaccine were severely hemorrhagic and edemic after challenge (Table 14). Birds receiving vaccine alone had severely atrophied bursas, and birds receiving vaccine and VNF had partially atrophied bursas after challenge.

Birds that were vaccinated with the mixture of IBD-BLEN™ and VNF showed significantly greater antibody titers to USDA-IBDV challenge than those receiving the IBD-BLEN™ alone (Table 15). This indicates that these birds would have carried a much higher protection after vaccination to any secondary infections throughout growout as compared to those receiving the virus vaccine alone. Again, one can see that antibody titer begins to fall off at the lowest dose of VNF when mixed with virus. This indicates that, if too much damage is caused to the bursa at vaccination, protection in terms of antibody titer is lost throughout the rest of the life of the bird.

TABLE 12

InOvo Vaccination with IBD-BLEN ™ and VNF and Effect on Hatchability and Mortality

	Hatchability		Mortality by D35		Mortality Post Chal	
Group No.	n	%	n	%	n	%
1	16/21	76.2^{A}	0/16	0.0^{A}	7/16	43.8^{B}
2	12/38	31.6^{B}	4/12	33.0^{A}	0/8	0.0^{B}
3	18/22	81.8^{A}	0/18	0.0^{A}	1/18	5.6^{B}
4	16/22	72.7^{A}	1/16	6.3^{A}	0/15	0.0^{B}
5	18/38	47.4^{AB}	5/18	27.8^{A}	1/13	7.7^{B}
6	15/21	71.4^{AB}	0/15	0.0^{A}	2/15	13.3^{B}
7	13/25	52.0^{a}	7/13	53.8^{ab}	1/6	16.6^{A}
8	11/25	44.0^{a}	10/11	90.9^{a}	0/1	0.0^{A}
9	7/25	28.0^{a}	1/7	14.3^{b}	0/6	0.0^{A}
10	8/25	32.0^{a}	0/8	0.0^{b}	0/8	0.0^{A}

Different superscripts designate significant differences by chi square analysis.

TABLE 13

In Ovo Vaccination with IBD-BLEN ™ and VNF and Effect on Body Weight Gain of SPF Chickens After USDA-IBDV Challenge on Day 35 Post Hatch

Group No.	Mean (g)	SEM	n
WEIGHT GAIN FROM DAY 35 TO DAY 39			
1	5.61^{B}	6.99	9
2	59.29^{A}	3.63	8
3	45.64^{A}	1.81	17
4	56.26^{A}	2.94	15
5	50.28^{A}	5.98	12
6	16.33^{B}	4.80	13
7	18.20^{c}	.62	5
8	57.90		1
9	43.35^{b}	6.26	6
10	62.60^{a}	4.64	8

Means with different superscripts differed significantly at the .05 level. (The SPAFAS .1X treatment was not included in the statistical analyses).

TABLE 14

Bursa Weight of SPF Chicken Groups After In Ovo Vaccination and Day 35 Post Hatch USDA-IBDV Challenge

Group No.	Mean (g)	SEM	n
BURSA WEIGHT DAY 39			
1	2.03^{A}	.29	9
2	$.55^{B}$	.20	8
3	$.73^{B}$	.07	17
4	$.62^{B}$	.12	15
5	$.47^{B}$	.09	12
6	2.05^{A}	.11	13
7	2.28^{a}	.23	5
8	.29	—	1
9	$.57^{b}$	.11	6
10	$.77^{b}$	.12	8

Means with different superscripts differed significantly at the .05 level. (The SPAFAS .1X treatment was not included in the statistical analyses).

TABLE 15

In Ovo Vaccination with IBD-BLEN ™ and VNF and Effect on Antibody Titer After USDA-IBDV Challenge TITERS (LOG 10)

Group No.	Mean	SD	SEM	n	Inverse Log Mean Titer
1	.66[c]	.71	.24	9	4.57
2	2.15[B]	.93	.33	8	141.25[1]
3	3.33[A]	.29	.07	17	2137.96[2]
4	3.31[A]	.40	.10	15	2041.74
5	2.95[A]	.76	.22	12	891.25
6	.61[c]	.59	.17	12	4.07
7	.85[b]	.54	.24	5	7.08
8	.30	.00	.00	1	2.00
9	3.30[a]	.20	.08	6	1995.26
10	3.25[a]	.62	.22	8	1778.28

Means with different superscripts differed significantly at the .05 level.
[1]In Group 2, 13% of the birds had titers greater than 1,000 and 87% had titers less than 1,000.
[2]In Group 3, 82% of the birds had titers greater than 1,000 and only 18% had titers less than 1,000.

EXAMPLE 12

Alternate Sources of VNF as Determined by the Chicken Fibroblast Assay

This Example demonstrates alternate sources of VNF with the chicken fibroblast assay described in Example 7 above.

Table 16 illustrates the viral neutralization titers against IBDV of serum samples from various birds as well as the corresponding Elisa titers. From this data one can see that some serum samples (HyLine chicken) have very high Elisa titers with correspondingly low viral neutralization titer. Hence, it is possible to have antibodies that bind very strongly to IBDV but do not neutralize IBDV. The HyLine chicken was challenged with RSV, regressed tumors, and produced binding antibodies against IBDV, but did not produce viral neutralizing antibodies against IBDV. The Arkansas regressor line chicken serum sample has both binding and neutralizing activity against IBDV.

An interesting observation is that unchallenged Jungle Fowl chickens from both the University of Arkansas and Mississippi State University produce serum with neutralizing antibodies against IBDV. Note also that Table 16 shows that VNF-like activity is found in the serum of a SPAFAS chicken that was innoculated with IBDV.

TABLE 16

Viral Neutralizing Activity and Elisa Titer of Various Serum Samples, VNF (5077D), and SPAFAS IBDV Antisera Against IBDV

Sample Origin	ED^{50} Titer	Units 50 μl	Units / ml	Units / ml[1]	Elisa Titer
VNF Peak II - TSK (1:4 dilution) (5077 D)	2,238	89.5	1,790	7,161	102,400
SPAFAS IBDV Antisera (1:100 dilution)	251	10	200	20,000	81,800
University of Arkansas Jungle Fowl (1:10 dilution)	398	15.9	318	3,180	25,600
University of Arkansas Regressor line sera (1:10 dilution)	112	4.5	90	900	12,800
Mississippi State University Jungle Fowl sera (1:10 dilution)	316	12.6	252	2,520	12,800
HyLine SC Line sera (1:5 dilution)	3.1	.12	2.4	12	819,200
Unchallenged University of Arkansas (1:5 dilution) Progressor line sera	3.9	.15	3	15	12,800
Challenged University of Arkansas (1:5 dilution) Progressor line sera	501	20	400	2,000	12,800

[1]Units corrected for dilution of original sample.

EXAMPLE 13

In Situ Vaccination Potential of VNF with Infectious Bursal Disease Virus

The object of this experiment was to test the efficacy of the VNF-IBD-BLEN™ mixture when administered by IM injection to chickens on 1–2 day post hatch to stimulate immunity to a secondary challenge of USDA-IBDV challenge virus.

Approximately 160 healthy 1 or 2 day old Hy-Vac chickens that are very susceptible to IBD-BLEN™ strain and are typically used in regulatory studies for licensing vaccines were used. Challenge of vaccinated birds was carried out with USDA Challenge Strain of Infectious Bursal Disease Virus (USDA-IBDV-CV) Lot #83-1, $10^{3.8}$ EID_{50}/ml. Standard vaccine against IBDV was obtained from SANOFI (IBD-BLEN™) at 1000 doses/vial, $10^{2.7}$ EID_{50}/dose. VNF from Arkansas regressor line birds as prepared as described above, 16,000 μg/ml in 1.5× Phosphate Buffered Saline, (PBS) pH 7.4. Its activity is determined by its viral neutralizing activity against Lukert's Strain of IBDV using Hy-Vac chicken fibroblasts in microneutralization assays. Purity was checked by HPLC.

Each chicken receiving the IBD-BLEN™ 1× or 0.1× dose vaccine received 100 μl of the IBD-BLEN™ preparation by IM injection into the thigh of the left leg. The 100 μl total volume will be composed of 50 μl IBD-BLEN™ (1× or 0.1×)+50 μl CEVA diluent. (Group 2—1× dose, Group 5—0.1× dose).

Each chicken receiving the IBD-BLEN™ 1×+VNF (Dose 1 or Dose 2) or 0.1×+VNF (Dose 1), received 100 μl of the vaccine mixture by IM injection. The 100 μl total volume was composed of 50 μl IBD-BLEN™ (1× or 0.1×)+50 μl VNF (Dose 1 or Dose 2). (Group 3—IBD-BLEN™ (1×)+VNF–Dose 1, Group 4—IBD-BLEN™ (1×)+VNF–Dose 2, Group 6—IBD-BLEN™ (0.1×)+VNF–Dose 1).

Each chicken receiving the VNF alone received 100 μl of the VNF preparation by IM injection. The 100 μl total volume will be composed of 50 μl VNF–Dose 1+50 μl CEVA diluent. (Group 7).

Each chicken receiving the USDA-IBDV challenge virus on Day 21 post vaccination will receive 30 μl of the preparation by eye drop in each eye. The 60 μl total volume required for both eyes is composed from a preparation of 1:8 dilution of stock USDA-IBDV virus which is 6309 EID_{50}/ml. (1.4 ml USDA-IBDV+9.8 ml CEVA diluent—23.5 EID_{50}/30 μl).

Data from this experiment are given in Table 17 below. Note that the birds in group 6 showed protection by day 10 from the vaccine virus in the virus-VNF conjugate. Hence, data from this study shows that it is possible to neutralize or inhibit a 0.1× dose of IBD-BLEN™ with 136 units of VNF so as to protect the bursa from the virus in the virus-VNF conjugate until day 10. Furthermore, when these birds are challenged on day 29 with USDA challenge strain, they show protection (no body weight loss, no mortality) from the challenge.

and bursa parameters at 21 days of age in chickens receiving inoculations of SANOFI IBD-BLEN™ that has been incubated with SC HyLINE sera and administered as a complete vaccine conjugate subcutaneously into the bird's neck.

Healthy one (1) day old HyVAC SPF chickens (about 90 total) that are susceptible to IBD-BLEN™ vaccination and USDA-IBDV challenge where used in these studies.

SC-Sera (≈35,000 μg/ml, #SC-2-22-90, ED_{50}/ml of 1:3,000,000) is whole sera which contains VNF and is produced by boosting SC HyLINE chickens with SANOFI IBD-BLEN™ in accordance with known procedures. VNF activity in this sera is determined by viral neutralization assays as described above.

IBD-BLEN™, and SC HyLINE sera where stored at 4° C. until ready for use. Once prepared, the IBD-BLEN™ vaccine and Sera-IBD-BLEN™ mixtures where held at room temperature for one (1) hour before inoculation.

TABLE 17

Summary of Body Weight Gain, Bursa Parameters, and IBD Antibody Titers for Example 13

Treatment Group	VNF Units/ 50 μl	Number Birds/ Group Day 40	Body Weight Gain Day 0–35	Body Weight Gain Day 35–40	Average Bursal Weight (gr) Day 10	Average Bursal Weight (gr) Day 35	Average Bursal Weight (gr) Day 40	Percent Lymphocytes Remaining in Bursa Day 10	Percent Lymphocytes Remaining in Bursa Day 40	IBDV Antibody Titer (% Hi) Day 10	IBDV Antibody Titer (% Hi) Day 35	IBDV Antibody Titer (% Hi) Day 40	Percent Mortality Day 35–40
SPF													
1 Control		7	^{A}401	^{D}–9	^{AB}.45	2.7	^{A}2.1	100	0	^{B}5	^{B}41	^{C}419	50
2 VACC 1X		22	^{C}337	^{C}44	^{C}.12		^{B}.8	20	60	^{A}347	^{A}1664(40)	^{B}1763(50)	0
3 VACC 1X VNF-1 (800 μg)	136	13	^{AB}381	^{BC}49	^{AB}.50		^{B}.7	35	38	^{B}2	^{A}3105(90)	^{A}3778(92)	0
4 VACC 1X VNF-2	14	16	^{ABC}365	^{AB}59	^{C}.15		^{B}.6	0	40	^{A}158	^{A}2172(60)	^{AB}3163(68)	0
5 VACC .1X	23		^{AB}372	^{BC}55	^{C}.13		^{B}1.0	5	78	^{A}467	^{A}1805(75)	^{AB}2705(77)	0
6 VACC .1X VNF-1 (800 μg)	136	13	^{A}379	^{A}69	^{A}.58		^{B}.5	90	15	^{B}2	^{A}2885(60)	^{A}4255(81)	0
7 VNF-1 (800 μg)	136	15	^{BC}343	^{D}6	^{B}.39		^{A}1.6	100	0	^{B}3	^{B}41	^{D}78	10

(%) = % of birds with ≧1000 IBDV antibody titer

^{ABCD}Means with different superscripts differed significantly at the .05 level.

EXAMPLE 14

In situ Vaccination Potential of HyLINE Sera with SANOFI IBD-BLEN™ Vacine When Administered Subcutaneously to HyVAC SPF Chickens

The object of this experiment was to evaluate immunological and pathological changes in terms of antibody titers

Data for the various experimental and control groups in this study are given in Table 18. These data demonstrate that, at concentrations of VNF equal to or greater than 316 Units, the bursa can be protected by weight at day 22 from the vaccine virus in the vaccine serum conjugate given at day 1.

TABLE 18

Day 1 Posthatch Dose Titration Vaccination in SPF Chickens Using SANOFI IBD-BLEN ™ Plus Viral Neutralization Factor (VNF) and Evaluation of Bursal Parameters at Day 21 Posthatch (Example 14)

Group Number	IBDV-BLEN ™ Dose[1]	VNF Units[2]	Body Weight	Bursa Weight	Relative Bursa Weight (g/kg)	Bursal Index	Titer Log-10	Titer INV Log
15	Negative		A	A	A	A	C	
	Control		178.8	1.07	5.94	100.00	.52	3
16	.01X	0	A	B	B	B	A	
			168.67	.27	1.57	26.44	3.10	1259
17	.01X	3159	A	A	A	A	B	
			177.4	1.06	5.73	96.48	1.0	11

TABLE 18-continued

Day 1 Posthatch Dose Titration Vaccination in SPF Chickens Using SANOFI IBD-BLEN ™ Plus Viral Neutralization Factor (VNF) and Evaluation of Bursal Parameters at Day 21 Posthatch (Example 14)

Group Number	IBDV-BLEN ™ Dose[1]	VNF Units[2]	Body Weight	Bursa Weight	Relative Bursa Weight (g/kg)	Bursal Index	Titer Log-10	Titer INV Log
18	.01X	316	A	A	A	A	C	
			178.8	1.01	5.61	94.48	.30	2
19	.01X	32	A	B	B	B	A	
			157.0	.25	1.63	27.53	2.63	427
20	.01X	3.2	A	B	B	B	A	
			173.1	.25	1.44	24.29	2.67	468

A, B, C = Means in a column processing different superscripts differed significantly at the .05 level
[1]A 0.01X dose of SANOFI IBD-BLEN ™ is 2.24 EID50/dose (Lot #29967).
[2]Viral neutralization activity expressed as units/50 μl dose.

EXAMPLE 15

Minimum Protective Dose of SC HyLINE Serum with Infectious Bursal Disease Virus Vaccine Administered Subcutaneously to HyVAC SPF Chickens

SANOFI IBD-BLEN™ is a virulent live virus vaccine capable of causing acute and chronic bursal lesions 3–9 days post vaccination in SPF chickens. Previous experiments utilizing this vaccine in 1 to 2 day old HyVAC SPF chickens have demonstrated bursal atrophy by day 10 to day 14 from intramuscular and subcutaneous inoculations of 1× through 0.0001× doses of IBD-BLEN™.

In this study, certain groups of one (1) day old HyVAC SPF chickens where vaccinated subcutaneously with various doses of SANOFI IBD-BLEN™ alone and in combination with various doses of SC HyLINE serum containing VNF. Vaccinated and control chickens where examined for bursal morphology as well as gross lesions at 15 or 22 days of age and challenged at 29 days of age with USDA-IBDV challenge strain to confirm immunogenicity (14, 21, and 28 days post vaccination). The object of this experiment is to evaluate immunological and pathological changes in terms of antibody titers and bursa parameters at 15 and 22 days of age in chickens receiving inoculations, at one (1) day of age (14, 21, and 28 days post vaccination), of various doses of SANOFI IBD-BLEN™ alone and incubated with various doses of SC HyLINE serum and administered as a complete vaccine. USDA-IBDV challenge occured at 29 days of age.

Healthy one (1) day old HyVAC SPF. chickens (630) that are susceptible to IBD-BLEN™ vaccination and USDA-IBDV challenge where used in this study. SC-Serum (40,000 μg/m, #5-18-90, ED_{50}/ml of ≈1:511,000) is whole serum which contains VNF and is produced by boosting SC HyLINE chickens with SANOFI IBD-BLEN™. VNF activity in this serum is determined by viral neutralization assays as described above. Commercial vaccine against IBDV, IBD-BLEN™, was provided by SANOFI Laboratories at 1000 doses/vial, $10^{2.3}$ EID_{50} titer. USDA-Challenge Strain of Infectious Bursal Disease Virus, Lot #83-3,$10^{3.8.}$ EID_{50}/ml, was used as a challenge. Vaccination was by subcutaneous injection and USDA-IBDV challenge was by eye drop at day 29 posthatch.

Data from this experiment are given in part in table 19. Our results show that, at a dose of 338 units of VNF and at a vaccine dose of 0.01× (2.24 EID_{50}/dose), bursas were protected from the vaccine virus at days 15 and 22, and were solidly immune to USDA challenge strain at day 29. After USDA challenge on day 29 there was normal body weight gain and no mortality in this group.

TABLE 19

Day 1 Posthatch Dose Titration Vaccination in SPF Chickens Using SANOFI IBD-BLEN Plus Viral Neutralization Factor (VNF) and Evaluation of Bursal Parameters and IBDV Antibody Titers at Day 15, Day 22, and 4 Days post USDA-IBDV Challenge[1] Given on Day 29[2] (Example 15)

Group	Isolator	IBDV-BLEN	VNF	Bursa Weight (gm)			Relative Bursa Weight (g/kg)			IBDV Antibody Titer (ELISA)		
Number	Number	Dose[3]	Units[4]	Day 15	Day 22	Day 33	Day 15	Day 22	Day 33	Day 15	Day 22	Day 33
1	6	Negative		.203*	.317*	.763*	1.54	1.54	2.04	366	917	2711
1	17	Control		.622	1.229	2.145	4.72	5.86	5.95	10	55	4
2	20	Positive		.600	1.151	1.064	4.57	5.83	4.02	9	104	52
2	16	Control		.710	1.222	1.576	5.18	5.91	5.55	57	67	46
3	9	.01x		.222	.362	.890	1.67	1.80	2.27	722	824	1720
3	2			.189	.401	.863	1.38	1.86	2.40	1055	1794	2480
4	1	.01x	338	.632	.397*	.482*	4.76	2.12	1.30	50	696	1645
4	3			.637	1.233	.559	4.78	6.03	1.60	16	39	1677
5	15	.01x	34	.641	1.166	1.866	4.74	5.78	5.71	27	11	38
5	19			.552	1.081	1.436	4.27	5.66	5.06	120	3	63
6	8	.001x		.194	.423	1.177	1.48	2.03	3.04	1201	1072	2037
6	12			.181	.376	.708	1.42	1.83	2.07	499	1182	1539
7	13	.001x	338	.661	1.340	1.824	4.74	6.54	5.45	40	34	74

TABLE 19-continued

Day 1 Posthatch Dose Titration Vaccination in SPF Chickens Using SANOFI IBD-BLEN Plus Viral Neutralization Factor (VNF) and Evaluation of Bursal Parameters and IBDV Antibody Titers at Day 15, Day 22, and 4 Days post USDA-IBDV Challenge[1] Given on Day 29[2] (Example 15)

Group	Isolator	IBDV-BLEN	VNF	Bursa Weight (gm)			Relative Bursa Weight (g/kg)			IBDV Antibody Titer (ELISA)		
Number	Number	Dose[3]	Units[4]	Day 15	Day 22	Day 33	Day 15	Day 22	Day 33	Day 15	Day 22	Day 33
7	18			.706	1.120	1.626	5.46	5.37	5.4	76	71	34
8	5	.001x	34	.707	1.122	1.492	5.06	5.74	4.48	17	168	26
8	11			.638	1.480	1.630	4.57	6.41	4.89	114	41	37
9	10	VNF alone	338	.604	1.222	1.752	4.60	6.38	4.96	50	130	72
9	14	1:3		.624	.983*	.440*	4.39	5.30	1.31	58	39	1163
10	7	VNF alone	34	.190*	.225*	0.449*	1.61	1.32	1.26	573	750	2636
10	4	1:30		.748	1.252	2.080	5.16	5.95	6.18	60	3	163
11	12	.0001x	3.4	.682	1.094	1.507	5.11	5.54	5.18	86	6	28

[1]USDA-IBDV Challenge strain administered by eye-drop at Day 29 posthatch at 47 EID_{50}/bird to every group except negative control.
[2]Statistical analysis not shown.
[3]A 0.01X dose of SANOFI IBD-BLEN contained 2.24 EID_{50}/dose (Lot #29967).
[4]Viral neutralizing activity is expressed as units/50 μl dose, whole serum containing VNF from SC Hyline chickens.
*Groups that were contaminated with IBDV.

The foregoing examples are illustrative of the present invention, and are not to be taken as limiting thereof. The invention is defined by the following claims, with equivalents of the claims to be included therein.

That which is claimed is:

1. A method of improving the safety of a vaccine virus that produces protective immunity against a viral disease in a mammalian subject, said method comprising:

administering to the subject a vaccine complex comprising a live vaccine virus and antibodies bound to said live vaccine virus;

wherein said live vaccine virus is capable of producing a protective immune response mammalian subject;

said antibodies are specific for said live vaccine virus and able to neutralize said live vaccine virus if provided in neutralizing amounts, said antibodies provided in an amount which delays pathological changes associated with infection of the subject by the vaccine virus compared to that which would occur if the live vaccine virus were administered without complexed antibodies, and said antibodies provided in an amount insufficient to neutralize said virus; and

said vaccine complex administered in an amount effective to produce a protective immune response to the live vaccine virus in the subject.

2. A method according to claim **1**, wherein the antibodies are selected from the group consisting of IgG immunoglobulins and IgG immunoglobulin fragments.

3. A method according to claim **1**, wherein the antibodies are polyclonal.

4. A method according to claim **1**, wherein the subject is administered the vaccine complex subcutaneously.

5. A method according to claim **1**, wherein the subject is administered the vaccine complex by intraperitoneal injection.

6. A method according to according to claim **1**, wherein the subject is administered the vaccine complex by intramuscular injection.

7. A method according to claim **1**, wherein the subject has not previously been infected by the live virus.

8. An improve vaccine preparation useful for more safely producing protective immunity against a viral disease in a mammalian subject, said vaccine preparation comprising:

a vaccine complex comprising a live vaccine virus and antibodies bound to said live vaccine virus;

wherein said live vaccine virus is capable of producing a protective immune response mammalian subject;

said antibodies are specific for said live vaccine virus and able to neutralize said live vaccine virus if provided in neutralizing amounts, said antibodies provided in an amount which delays pathological changes associated with infection of the subject by the vaccine virus compared to that which would occur if the live vaccine virus were administered without complexed antibodies, and said antibodies provided in an amount insufficient to neutralize said virus;

said vaccine complex included in said vaccine preparation in an amount effective to produce a protected immune response to said live vaccine virus in said subject.

9. A vaccine preparation as claimed in claim **8**, wherein said vaccine preparation is lyophylized.

10. A vaccine preparation as claimed in claim **8**, wherein said vaccine preparation further comprises a pharmaceutically acceptable carrier.

11. A vaccine preparation as claimed in claim **10**, wherein said pharmaceutically acceptable carrier is a liquid carrier.

12. A vaccine preparation as claimed in claim **10**, wherein said pharmaceutically acceptable carrier is an aqueous carrier.

13. A vaccine preparation as claimed in claim **8**, said vaccine preparation further comprising an adjuvant.

14. A vaccine preparation as claimed in claim **8**, said vaccine preparation further comprising a stabilizer.

15. A vaccine preparation as claimed in claim **8**, wherein said antibodies are selected from the group consisting of IgG immunoglobulins and IgG immunoglobulin fragments.

16. A vaccine preparation as claimed in claim **8**, wherein said antibodies are polyclonal.

17. An article of manufacture comprising a closed, pathogen-impermeable container and a sterile vaccine preparation enclosed within said container, said vaccine preparation useful for more safely producing protective immunity against a viral disease in a mammalian subject, said vaccine preparation comprising:

a pharmaceutically acceptable formulation comprising a vaccine complex;

said vaccine complex comprising a live vaccine virus and antibodies bound to said live vaccine virus;

wherein said live vaccine virus is capable of producing a protective immune response in a mammalian subject;

said antibodies am specific for said live vaccine virus and able to neutralize said live vaccine virus if provided in neutralizing amounts,

said antibodies provided in an amount which delays pathological changes associated with infection of the subject by the vaccine virus compared to that which would occur if the live vaccine virus were administered without complexed antibodies, and said antibodies provided in an amount insufficient to neutralize said virus;

said vaccine complex included in said pharmaceutically acceptable formulation in an amount effective to produce a protective immune response to said live vaccine virus in said subject.

18. An article of manufacture as claimed in claim **17**, wherein said pharmaceutically acceptable formulation is lyophylized.

19. An article of manufacture as claimed in claim **17**, wherein said pharmaceutically acceptable formulation further comprises a pharmaceutically acceptable carrier.

20. An article of manufacture as claimed in claim **19**, wherein said pharmaceutically acceptable carrier is a liquid carrier.

21. An article of manufacture as claimed in claim **19**, wherein said pharmaceutically acceptable carrier is an aqueous carrier.

22. An article of manufacture as claimed in claim **17**, said pharmaceutically acceptable formulation further comprising an adjuvant.

23. An article of manufacture as claimed in claim **17**, said pharmaceutically acceptable formulation further comprising a stabilizer.

24. An article of manufacture as claimed in claim **17**, wherein said antibodies are selected from the group consisting of IgG immunoglobulins and IgG immunoglobulin fragments.

25. An article of manufacture as claimed in claim **17**, wherein said antibodies are polyclonal.

26. A method of improving the safety of a vaccine virus that produces protective immunity against a viral disease in a mammalian subject, said method comprising:

administering to the subject a vaccine complex comprising a live vaccine virus and antibodies bound to said live vaccine virus;

wherein said live vaccine virus is capable of producing a protective immune response in a mammalian subject, said live vaccine virus selected from the group consisting of a Japanese Encephalitis virus, an influenza virus, Sendai virus, measles virus, and pseudorabies virus;

said antibodies are specific for said live vaccine virus and able to neutralize said live vaccine virus if provided in neutralizing amounts, said antibodies provided in an amount which delays pathological changes associated with infection of the subject by the vaccine virus compared to that which would occur if the live vaccine virus were administered without complexed antibodies, and said antibodies provided in an amount insufficient to neutralize said virus; and

said vaccine complex administered in an amount effective to produce a protective immune response to the live vaccine virus in the subject.

27. An improved vaccine preparation useful for more safely producing protective immunity against a viral disease in a mammalian subject, said vaccine preparation comprising:

a vaccine complex comprising a live vaccine virus and antibodies bound to said live vaccine virus;

wherein said live vaccine virus is capable of producing a protective immune response in a mammalian subject, said live vaccine virus is selected from the group consisting of a Japanese Encephalitis virus, an influenza virus, Sendai virus, measles virus, and pseudorabies virus;

said antibodies specific for said live vaccine virus and able to neutralize said live vaccine virus if provided in neutralizing amounts, said antibodies provided in an amount which delays pathological changes associated with infection of the subject by the vaccine virus compared to that which would occur if the live vaccine virus were administered without complexed antibodies, and said antibodies provided in an amount insufficient to neutralize said virus;

said vaccine complex included in said vaccine preparation in an amount effective to produce a protective immune response to said live vaccine virus in said subject.

28. An article of manufacture comprising a closed, pathogen-impermeable container and a sterile vaccine preparation enclosed within said container, said vaccine preparation useful for more safely producing protective immunity against a viral disease in a mammalian subject, said vaccine preparation comprising:

a pharmaceutically acceptable formulation comprising a vaccine complex;

said vaccine complex comprising a live vaccine virus and antibodies bound to said live vaccine virus;

wherein said live vaccine virus is capable of producing a protective immune response in a mammalian subject; said live vaccine virus is selected from the group consisting of a Japanese Encephalitis virus, an influenza virus, Sendai virus, measles virus, and pseudorabies virus;

said antibodies are specific for said live vaccine virus and able to neutralize said live vaccine virus if provided in neutralizing amounts, said antibodies provided in an amount which delays pathological changes associated with infection of the subject by the vaccine virus compared to that which would occur if the live vaccine virus were administered without complexed antibodies, and said antibodies provided in an amount insufficient to neutralize said virus;

said vaccine complex included in said pharmaceutically acceptable formulation in an amount effective to produce a protective immune response to said live vaccine virus in said subject.

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