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(54) Titre : VACCINS A PARTICULES PSEUDO-VIRALES (VLP) DE PARVOVIRUS CANIN (CPV) ET UTILISATIONS ASSOCIEES

(54) Title: CANINE PARVOVIRUS (CPV) VIRUS-LIKE PARTICLE (VLP) VACCINES AND USES THEREOF

(57) Abrégé/Abstract:
The present invention encompasses canine parvovirus (CPV) vaccines or compositions. The vaccine or composition may be a vaccine or composition containing CPV virus-like particle (VLP), and a preparation method and a use thereof. The CPV VLPs provided by the invention are formed by the CPV VP2 protein. Further, the invention broadly encompasses vaccines comprising combinations of MLV and VLP, which are capable of overcoming MDA against a variety of pathogens, which infect a variety of different species.

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(57) **Abstract**: The present invention encompasses canine parvovirus (CPV) vaccines or compositions. The vaccine or composition may be a vaccine or composition containing CPV virus-like particle (VLP), and a preparation method and a use thereof. The CPV VLPs provided by the invention are formed by the CPV VP2 protein. Further, the invention broadly encompasses vaccines comprising combinations of MLV and VLP, which are capable of overcoming MDA against a variety of pathogens, which infect a variety of different species.

Canine Parvovirus (CPV) Virus-like Particle (VLP) Vaccines and uses thereof

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to USSN 62/234,196, filed on 29 September 2015, and herein incorporated by reference in its entirety. All other references cited herein are similar incorporated by reference in their entireties.

STATEMENT REGARDING SEQUENCE LISTING

[0002] The Sequence Listing associated with this application is provided in text format in lieu of a paper copy, and is hereby incorporated by reference into the specification. The name of the text file containing the Sequence Listing is MER 14-252P_ST25.txt. The text file is 82 KB; it was created on July 13, 2015; and it is being submitted electronically via EFS-Web, concurrent with the filing of the specification.

FIELD OF THE INVENTION

[0003] The present invention relates to the field of vaccinology, and more particularly, to the challenge of overcoming maternally-derived antibodies (MDA). More particularly, the invention relates to overcoming MDA by administering to animals, including dogs, a combination of virus-like particles and modified live virus (MLV), either in simultaneous combination, sequential administration, or via a prime-boost administration regime. Even more particularly, the invention relates to compositions for eliciting protective immunity against parvovirus (CPV) in dogs and puppies, whether or not CPV MDA are present in the dogs and puppies.

BACKGROUND OF THE INVENTION

[0004] Canine parvovirus (CPV) is primarily an enteric pathogen that infects dogs, especially young dogs. Parvovirus infection is characterized by acute diarrhea, fever and leukopenia in dogs and puppies more than 4 to 5 weeks old, and in rare cases myocardial disease in younger puppies. The mortality rate from the disease in unvaccinated dogs is very high. And while several CPV vaccines exist, the presence of maternally-derived antibodies (MDA) tends to block the ability of otherwise effective vaccines to provide protective immunity.

[0005] Newborn puppies acquire passive immunities against diseases such as CPV infection by nursing from their mother, especially during the first two days of life. A puppy that nurses takes in colostrum in the milk that is first produced and (MDA) in the colostrum are passed to the puppy. For dogs—and many other mammals—the level of passive immunity provided by the colostrum gradually decreases as MDA are catabolized. As such, the age at which a puppy is no

longer protected by MDA varies widely, depending upon the puppy's intake of colostrum, the amount of antibodies contained therein, and several other factors.

[0006] A particular challenge when vaccinating puppies is to administer vaccines according to a time frame that provides protection which overlaps the protection provided by maternal antibodies and begins as maternal antibodies wane. Currently, vaccine regimens for puppies typically begin at about 6 weeks of age and boosters are given about every 3 weeks thereafter, e.g. at 9, 12 and sometimes 15 weeks. However, in order for this regimen to provide full protection, the first vaccine dose would have to immediately elicit a protective immune response. This expectation is entirely unrealistic due, in part, to the immaturity of the puppy's immune system and the time period required to mount an immune response. Moreover, the situation is further complicated because residual MDA, which may persist up to about six weeks of age, neutralize MLV vaccines. Currently, all commercially available CPV vaccines are MLV vaccines.

[0007] Importantly, while a puppy with CPV MDA may not respond to any MLV CPV vaccine, it can still be infected by a virulent field strain of CPV, and develop canine parvovirosis. Because of the MDA interference, full protection usually does not develop until the entire course of vaccinations is given. As a consequence, the age-based mortality due to CPV infection peaks prior to completion of vaccination protocols. Accordingly, developing a vaccine that actively immunizes puppies after the first injection—and in the presence of MDA—is one of the most important unmet needs in canine medicine.

[0008] Another challenge in veterinary medicine is the treatment of cancer, e.g., in dogs. There are many limitations in the existing tools for cancer therapy, especially for geriatric dogs. The administration of oncolytic parvoviruses to kill cancer cells shows great promise as an effective cancer treatment (Rommelaere et al, Cytokine & Growth Factor Reviews 21:185-195, 2010; and U.S. Pat. No. 7,179,456 to Rommelaere et al, the complete contents of which are herein incorporated by reference) and might be applied to canines. However, the existence of pre-existing antibodies to parvoviruses (e.g. as a result of vaccination) would render this method ineffective, since the parvovirus would be neutralized by the existing antibodies. In addition, gene therapy in dogs is rarely undertaken at present but would be a promising method for treating several disorders, if suitable nucleic acid vectors are identified. Accordingly, methods to overcome existing antibodies would be useful for applications beyond vaccination.

[0009] In light of the above, there is a need for vaccines with an improved safety and a good efficacy, including the ability to overcome MDA including vaccines that provide protection against heterologous CPV strains.

SUMMARY OF THE INVENTION

[0010] The present invention provides pharmaceutical compositions comprising CPV virus-like particle (VLP) antigens, CPV modified live virus (MLV) vaccines, methods of vaccination against CPV, and kits for use with such methods and compositions.

[0011] Compositions or vaccines comprising an antigenic CPV polypeptide and fragments and variants thereof are provided. The CPV antigens and fragments and variants thereof possess immunogenic and protective properties. The CPV antigens may be produced by a baculovirus expression vector in insect cells, and assemble into CPV empty capsids or CPV VLPs (virus-like particles).

[0012] The antigenic polypeptides and fragments and variants thereof can be formulated into vaccines with or without CPV modified live viruses and/or pharmaceutical compositions. Such vaccines or compositions can be used to vaccinate an animal and provide protection against homologous and heterologous CPV strains.

[0013] Importantly, the inventors have surprisingly and unexpectedly found that administration of compositions comprising both a MLV and a VLP (each an antigen corresponding to the same pathogen, but not necessarily encoding or providing the same portion or gene or subunit thereof), is capable of overcoming MDA to elicit protective immunity against subsequent virulent challenge by said pathogen. Accordingly, in a particular embodiment, the invention provides combination vaccines comprising both MLV CPV and CPV VLP, which elicit protective immunity in puppies whether or not the puppies have circulating MDA against CPV.

[0014] In another embodiment, the invention provides combination vaccines comprising both MLV and VLP corresponding to other pathogens, where MDA interference is a concern. For example, young bovines, porcines, felines, caprines, ovines, equines and others have circulating MDA against various pathogens. In each case, the presence of these MDA may interfere with the efficacy of vaccines. Now that this disclosure has been made, the inventors envision that administering a combination of both MLV + VLP will overcome MDA irrespective of the pathogen. Pathogens may include, but are not limited to: foot-and-mouth-disease virus (FMDV), porcine reproductive and respiratory syndrome virus (PRRSV), canine distemper virus (CDV), feline panleukopenia FPL, and equine influenza virus (EIV). The skilled person will

appreciate that this approach, providing MLV + VLP may be applied in any case where interference by MDA is a challenge.

[0015] Kits comprising at least one antigenic polypeptide or fragment or variant thereof and instructions for use are also provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The following detailed description, given by way of example, but not intended to limit the invention solely to the specific embodiments described, may best be understood in conjunction with the accompanying drawings, in which:

[0017] FIG. 1 depicts a table summarizing the DNA and Protein sequences;

[0018] FIG. 2 depicts the plasmid map of pMEB072;

[0019] FIG. 3 depicts the plasmid map of pMEB073;

[0020] FIG. 4 is an electron micrograph of CPV VLPs, showing the correct shape and morphology for parvovirus-like virions;

[0021] FIG. 5 is a Western Blot showing levels of CPV VLPs and accompanying data;

[0022] FIG. 6 is a Western Blot showing levels of CPV VLPs and accompanying data;

[0023] FIG. 7 is a graph showing ELISA-determined CPV titers post vaccination;

[0024] FIG. 8 is a graph showing ELISA-determined CPV titers post vaccination with Souriou & Bari strains (low dose, no adjuvant) or pMEB072-produced CPV VLP. Onset is more rapid in group receiving VLP;

[0025] FIG. 9 is a graph showing ELISA-determined CPV titers post vaccination with Souriou & Bari strains (intermediate dose, with adjuvant) or pMEB073-produced CPV VLP (with $Al(OH)_3$+saponin). Onset is still more rapid in group receiving VLP;

[0026] FIG. 10 is a graph showing ELISA-determined CPV titers post vaccination with Souriou & Bari strains (high dose) or pMEB073-produced CPV VLP (with $Al(OH)_3$+saponin). Onset is rapid with all three groups;

[0027] FIG. 11 is a ClustalW alignment of SEQ ID NOs: 1, 3, 4 and 6;

[0028] FIG. 12 is a graph showing individual anti-CPV antibody titers (IHA) according to treatment (MLV or MLV + VLP on D0) and day. Each line corresponds to one individual, and

the size of the points corresponds to number of values at the indicated combination of day and titer. Only data from dogs having D0 IHA titer ≥ 40 are shown;

[0029] FIG. 13 is a graph showing mean anti-CPV antibody titers (IHA) according to treatment (MLV or MLV + VLP on D0) and day. Boxes represent median, 25th and 75th percentiles, and ends of the whiskers represent values within 1.5 times the interquartile range; each symbol represents one value;

[0030] FIG. 14 is a graph showing mean anti-CPV antibody titers (determined by ELISA log10 OD50) according to day post vaccination and group (Gr A: VLP SC 500 µl; Gr D VLP oral; Gr E Ad5 CPV 8.64 log10; Gr G Ad5 CDV). Dogs were vaccinated on D0 and D28. Means are represented +/- one standard error of the mean; each dot represents one value;

[0031] FIG. 15 is a graph showing percent responders for the study disclosed in Example 7;

[0032] FIG. 16 is a graph showing HAI titers;

[0033] FIG. 17 is a graph showing Geometric Mean Titer of CPV-neutralizing Antibodies

[0034] FIG. 18 is a graph showing Percentage Responders by Group and Day;

[0035] FIG. 19 is a graph showing CPV Geometric Mean Antibody titer by Group and Day.

DETAILED DESCRIPTION

[0036] Compositions comprising a CPV polypeptide, antigen and fragments and variants thereof that elicit an immunogenic response in an animal are provided. The antigenic polypeptides or fragments or variants thereof are produced by a baculovirus expression vector in insect cells. The antigenic polypeptides or fragments or variants may be formulated into vaccines with or without CPV modified live viruses or pharmaceutical compositions and used to elicit or stimulate a protective response in an animal. In one embodiment the polypeptide antigen is a CPV capsid polypeptide or active fragment or variant thereof. The CPV antigens may be assembled into CPV empty capsids or CPV VLPs (virus-like particles).

[0037] It is recognized that the antigenic polypeptides of the invention may be full length polypeptides or active fragments or variants thereof. By “active fragments” or “active variants” is intended that the fragments or variants retain the antigenic nature of the polypeptide. Thus, the present invention encompasses any CPV polypeptide, antigen, epitope or immunogen that elicits an immunogenic response in an animal. The CPV polypeptide, antigen, epitope or immunogen may be any CPV polypeptide, antigen, epitope or immunogen, such as, but not limited to, a

protein, peptide or fragment or variant thereof, that elicits, induces or stimulates a response in an animal, such as an ovine, bovine, caprine or porcine.

[0038] The present invention relates to canine vaccines or compositions which may comprise an effective amount of a recombinant CPV antigen. In some embodiments, the vaccines or compositions are non-adjuvanted, and may comprise a pharmaceutically or veterinarily acceptable carrier, excipient, or vehicle.

[0039] In some embodiments, the response in the animal is a protective immune response.

[0040] By "animal" it is intended mammals, birds, and the like. Animal or host includes mammals and human. The animal may be selected from the group consisting of equine (e.g., horse), canine (e.g., dogs, wolves, foxes, coyotes, jackals), feline (e.g., lions, tigers, domestic cats, wild cats, other big cats, and other felines including cheetahs and lynx), ovine (e.g., sheep), bovine (e.g., cattle), swine (e.g., pig), caprine (e.g., goat), avian (e.g., chicken, duck, goose, turkey, quail, pheasant, parrot, finches, hawk, crow, ostrich, emu and cassowary), primate (e.g., prosimian, tarsier, monkey, gibbon, ape), and fish. The term "animal" also includes an individual animal in all stages of development, including embryonic and fetal stages.

[0041] Unless otherwise explained, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. The singular terms "a", "an", and "the" include plural referents unless context clearly indicates otherwise. Similarly, the word "or" is intended to include "and" unless the context clearly indicate otherwise.

[0042] It is noted that in this disclosure and particularly in the claims and/or paragraphs, terms such as "comprises", "comprised", "comprising" and the like can have the meaning attributed to it in U.S. Patent law; e.g., they can mean "includes", "included", "including", and the like; and that terms such as "consisting essentially of" and "consists essentially of" have the meaning ascribed to them in U.S. Patent law, e.g., they allow for elements not explicitly recited, but exclude elements that are found in the prior art or that affect a basic or novel characteristic of the invention.

[0043] The antigenic polypeptides of the invention are capable of protecting against CPV. That is, they are capable of stimulating an immune response in an animal. By "antigen" or "immunogen" means a substance that induces a specific immune response in a host animal. The antigen may comprise a whole organism, killed, attenuated or live; a subunit or portion of an organism; a recombinant vector containing an insert with immunogenic properties; a piece or

fragment of DNA capable of inducing an immune response upon presentation to a host animal; a polypeptide, an epitope, a hapten, or any combination thereof. Alternately, the immunogen or antigen may comprise a toxin or antitoxin.

[0044] The term “immunogenic protein, polypeptide, or peptide” as used herein includes polypeptides that are immunologically active in the sense that once administered to the host, it is able to evoke an immune response of the humoral and/or cellular type directed against the protein. Preferably the protein fragment is such that it has substantially the same immunological activity as the total protein. Thus, a protein fragment according to the invention comprises or consists essentially of or consists of at least one epitope or antigenic determinant. An "immunogenic" protein or polypeptide, as used herein, includes the full-length sequence of the protein, analogs thereof, or immunogenic fragments thereof. By "immunogenic fragment" is meant a fragment of a protein which includes one or more epitopes and thus elicits the immunological response described above. Such fragments can be identified using any number of epitope mapping techniques, well known in the art. See, e.g., Epitope Mapping Protocols in Methods in Molecular Biology, Vol. 66 (Glenn E. Morris, Ed., 1996). For example, linear epitopes may be determined by e.g., concurrently synthesizing large numbers of peptides on solid supports, the peptides corresponding to portions of the protein molecule, and reacting the peptides with antibodies while the peptides are still attached to the supports. Such techniques are known in the art and described in, e.g., U.S. Pat. No. 4,708,871; Geysen et al., 1984; Geysen et al., 1986. Similarly, conformational epitopes are readily identified by determining spatial conformation of amino acids such as by, e.g., x-ray crystallography and 2-dimensional nuclear magnetic resonance. See, e.g., Epitope Mapping Protocols, supra. Methods especially applicable to the proteins of *T. parva* are fully described in PCT/US2004/022605 incorporated herein by reference in its entirety.

[0045] As discussed the invention encompasses active fragments and variants of the antigenic polypeptide. Thus, the term “immunogenic protein, polypeptide, or peptide” further contemplates deletions, additions and substitutions to the sequence, so long as the polypeptide functions to produce an immunological response as defined herein. The term "conservative variation" denotes the replacement of an amino acid residue by another biologically similar residue, or the replacement of a nucleotide in a nucleic acid sequence such that the encoded amino acid residue does not change or is another biologically similar residue. In this regard, particularly preferred substitutions will generally be conservative in nature, i.e., those substitutions that take place within a family of amino acids. For example, amino acids are generally divided into four families: (1) acidic--aspartate and glutamate; (2) basic--lysine,

arginine, histidine; (3) non-polar--alanine, valine, leucine, isoleucine, proline, phenylalanine, methionine, tryptophan; and (4) uncharged polar--glycine, asparagine, glutamine, cysteine, serine, threonine, tyrosine. Phenylalanine, tryptophan, and tyrosine are sometimes classified as aromatic amino acids. Examples of conservative variations include the substitution of one hydrophobic residue such as isoleucine, valine, leucine or methionine for another hydrophobic residue, or the substitution of one polar residue for another polar residue, such as the substitution of arginine for lysine, glutamic acid for aspartic acid, or glutamine for asparagine, and the like; or a similar conservative replacement of an amino acid with a structurally related amino acid that will not have a major effect on the biological activity. Proteins having substantially the same amino acid sequence as the reference molecule but possessing minor amino acid substitutions that do not substantially affect the immunogenicity of the protein are, therefore, within the definition of the reference polypeptide. All of the polypeptides produced by these modifications are included herein. The term "conservative variation" also includes the use of a substituted amino acid in place of an unsubstituted parent amino acid provided that antibodies raised to the substituted polypeptide also immunoreact with the unsubstituted polypeptide.

[0046] The term "epitope" refers to the site on an antigen or hapten to which specific B cells and/or T cells respond. The term is also used interchangeably with "antigenic determinant" or "antigenic determinant site". Antibodies that recognize the same epitope can be identified in a simple immunoassay showing the ability of one antibody to block the binding of another antibody to a target antigen.

[0047] An "immunological response" to a composition or vaccine is the development in the host of a cellular and/or antibody-mediated immune response to a composition or vaccine of interest. Usually, an "immunological response" includes but is not limited to one or more of the following effects: the production of antibodies, B cells, helper T cells, and/or cytotoxic T cells, directed specifically to an antigen or antigens included in the composition or vaccine of interest. Preferably, the host will display either a therapeutic or protective immunological response such that resistance to new infection will be enhanced and/or the clinical severity of the disease reduced. Such protection will be demonstrated by either a reduction or lack of symptoms normally displayed by an infected host, a quicker recovery time and/or a lowered viral titer in the infected host.

[0048] Synthetic antigens are also included within the definition, for example, polyepitopes, flanking epitopes, and other recombinant or synthetically derived antigens. See, e.g., Bergmann

et al., 1993; Bergmann et al., 1996; Suhrbier, 1997; Gardner et al., 1998. Immunogenic fragments, for purposes of the present invention, will usually include at least about 3 amino acids, at least about 5 amino acids, at least about 10-15 amino acids, or about 15-25 amino acids or more amino acids, of the molecule. There is no critical upper limit to the length of the fragment, which could comprise nearly the full-length of the protein sequence, or even a fusion protein comprising at least one epitope of the protein.

[0049] Accordingly, a minimum structure of a polynucleotide expressing an epitope is that it comprises or consists essentially of or consists of nucleotides encoding an epitope or antigenic determinant of a CPV polypeptide. A polynucleotide encoding a fragment of a CPV polypeptide may comprise or consist essentially of or consist of a minimum of 15 nucleotides, about 30-45 nucleotides, about 45-75, or at least 57, 87 or 150 consecutive or contiguous nucleotides of the sequence encoding the polypeptide. Epitope determination procedures, such as, generating overlapping peptide libraries (Hemmer et al., 1998), Pepscan (Geysen et al., 1984; Geysen et al., 1985; Van der Zee R. et al., 1989; Geysen, 1990; Multipin. RTM. Peptide Synthesis Kits de Chiron) and algorithms (De Groot et al., 1999; PCT/US2004/022605) can be used in the practice of the invention.

[0050] The term “nucleic acid” and “polynucleotide” refers to RNA or DNA that is linear or branched, single or double stranded, or a hybrid thereof. The term also encompasses RNA/DNA hybrids. The following are non-limiting examples of polynucleotides: a gene or gene fragment, exons, introns, mRNA, tRNA, rRNA, ribozymes, cDNA, recombinant polynucleotides, branched polynucleotides, plasmids, vectors, isolated DNA of any sequence, isolated RNA of any sequence, nucleic acid probes and primers. A polynucleotide may comprise modified nucleotides, such as methylated nucleotides and nucleotide analogs, uracyl, other sugars and linking groups such as fluororibose and thiolate, and nucleotide branches. The sequence of nucleotides may be further modified after polymerization, such as by conjugation, with a labeling component. Other types of modifications included in this definition are caps, substitution of one or more of the naturally occurring nucleotides with an analog, and introduction of means for attaching the polynucleotide to proteins, metal ions, labeling components, other polynucleotides or solid support. The polynucleotides can be obtained by chemical synthesis or derived from a microorganism.

[0051] The term “gene” is used broadly to refer to any segment of polynucleotide associated with a biological function. Thus, genes include introns and exons as in genomic sequence, or just the coding sequences as in cDNAs and/or the regulatory sequences required for their

expression. For example, gene also refers to a nucleic acid fragment that expresses mRNA or functional RNA, or encodes a specific protein, and which includes regulatory sequences.

[0052] The invention further comprises a complementary strand to a polynucleotide encoding a CPV antigen, epitope or immunogen. The complementary strand can be polymeric and of any length, and can contain deoxyribonucleotides, ribonucleotides, and analogs in any combination.

[0053] The terms “protein”, “peptide”, “polypeptide” and “polypeptide fragment” are used interchangeably herein to refer to polymers of amino acid residues of any length. The polymer can be linear or branched, it may comprise modified amino acids or amino acid analogs, and it may be interrupted by chemical moieties other than amino acids. The terms also encompass an amino acid polymer that has been modified naturally or by intervention; for example disulfide bond formation, glycosylation, lipidation, acetylation, phosphorylation, or any other manipulation or modification, such as conjugation with a labeling or bioactive component.

[0054] An “isolated” biological component (such as a nucleic acid or protein or organelle) refers to a component that has been substantially separated or purified away from other biological components in the cell of the organism in which the component naturally occurs, for instance, other chromosomal and extra-chromosomal DNA and RNA, proteins, and organelles. Nucleic acids and proteins that have been “isolated” include nucleic acids and proteins purified by standard purification methods. The term also embraces nucleic acids and proteins prepared by recombinant technology as well as chemical synthesis.

[0055] The term “purified” as used herein does not require absolute purity; rather, it is intended as a relative term. Thus, for example, a purified polypeptide preparation is one in which the polypeptide is more enriched than the polypeptide is in its natural environment. That is the polypeptide is separated from cellular components. By “substantially purified” it is intended that such that the polypeptide represents several embodiments at least 60%, at least 70%, at least 80%, at least 90%, at least 95%, or at least 98%, or more of the cellular components or materials have been removed. Likewise, the polypeptide may be partially purified. By “partially purified” is intended that less than 60% of the cellular components or material is removed. The same applies to polynucleotides. The polypeptides disclosed herein can be purified by any of the means known in the art.

[0056] As noted above, the antigenic polypeptides or fragments or variants thereof are CPV antigenic polypeptides that are produced by a baculovirus expression vector in insect cells. Fragments and variants of the disclosed polynucleotides and polypeptides encoded thereby are

also encompassed by the present invention. By “fragment” is intended a portion of the polynucleotide or a portion of the antigenic amino acid sequence encoded thereby. Fragments of a polynucleotide may encode protein fragments that retain the biological activity of the native protein and hence have immunogenic activity as noted elsewhere herein. Fragments of the polypeptide sequence retain the ability to induce a protective immune response in an animal.

[0057] “Variants” is intended to mean substantially similar sequences. For polynucleotides, a variant comprises a deletion and/or addition of one or more nucleotides at one or more sites within the native polynucleotide and/or a substitution of one or more nucleotides at one or more sites in the native polynucleotide. As used herein, a “native” polynucleotide or polypeptide comprises a naturally occurring nucleotide sequence or amino acid sequence, respectively. Variants of a particular polynucleotide of the invention (i.e., the reference polynucleotide) can also be evaluated by comparison of the percent sequence identity between the polypeptide encoded by a variant polynucleotide and the polypeptide encoded by the reference polynucleotide. “Variant” protein is intended to mean a protein derived from the native protein by deletion or addition of one or more amino acids at one or more sites in the native protein and/or substitution of one or more amino acids at one or more sites in the native protein. Variant proteins encompassed by the present invention are biologically active, that is they the ability to elicit an immune response.

[0058] In one aspect, the present invention provides CPV polypeptides from CPV isolates. In another aspect, the present invention provides a polypeptide having a sequence as set forth in SEQ ID NOs: 1, 3, 4, 6, 8-10, and variant or fragment thereof.

[0059] In another aspect, the invention relates to CPV empty capsids or CPV VLPs (virus-like particles). The capsids may comprise, consist essentially of, or consist of CPV VP2 polypeptides, or variants, including truncated versions thereof.

[0060] Moreover, homologs of CPV polypeptides are intended to be within the scope of the present invention. As used herein, the term “homologs” includes orthologs, analogs and paralogs. The term “analogs” refers to two polynucleotides or polypeptides that have the same or similar function, but that have evolved separately in unrelated organisms. The term “orthologs” refers to two polynucleotides or polypeptides from different species, but that have evolved from a common ancestral gene by speciation. Normally, orthologs encode polypeptides having the same or similar functions. The term “paralogs” refers to two polynucleotides or polypeptides that are related by duplication within a genome. Paralogs usually have different functions, but these functions may be related. Analogs, orthologs, and paralogs of a wild-type CPV polypeptide

can differ from the wild-type CPV polypeptide by post-translational modifications, by amino acid sequence differences, or by both. In particular, homologs of the invention will generally exhibit at least 80-85%, 85-90%, 90-95%, or 95%, 96%, 97%, 98% , 99% sequence identity, with all or part of the wild-type CPV polynucleotide sequences, and will exhibit a similar function. Variants include allelic variants. The term "allelic variant" refers to a polynucleotide or a polypeptide containing polymorphisms that lead to changes in the amino acid sequences of a protein and that exist within a natural population (e.g., a virus species or variety). Such natural allelic variations can typically result in 1- 5% variance in a polynucleotide or a polypeptide. Allelic variants can be identified by sequencing the nucleic acid sequence of interest in a number of different species, which can be readily carried out by using hybridization probes to identify the same gene genetic locus in those species. Any and all such nucleic acid variations and resulting amino acid polymorphisms or variations that are the result of natural allelic variation and that do not alter the functional activity of gene of interest, are intended to be within the scope of the invention.

[0061] As used herein, the term "derivative" or “variant” refers to a polypeptide, or a nucleic acid encoding a polypeptide, that has one or more conservative amino acid variations or other minor modifications such that (1) the corresponding polypeptide has substantially equivalent function when compared to the wild type polypeptide or (2) an antibody raised against the polypeptide is immunoreactive with the wild-type polypeptide. These variants or derivatives include polypeptides having minor modifications of the CPV polypeptide primary amino acid sequences that may result in peptides which have substantially equivalent activity as compared to the unmodified counterpart polypeptide. Such modifications may be deliberate, as by site-directed mutagenesis, or may be spontaneous. The term “variant” further contemplates deletions, additions and substitutions to the sequence, so long as the polypeptide functions to produce an immunological response as defined herein.

[0062] The term "conservative variation" denotes the replacement of an amino acid residue by another biologically similar residue, or the replacement of a nucleotide in a nucleic acid sequence such that the encoded amino acid residue does not change or is another biologically similar residue. In this regard, particularly preferred substitutions will generally be conservative in nature, as described above.

[0063] The polynucleotides of the disclosure include sequences that are degenerate as a result of the genetic code, e.g., optimized codon usage for a specific host. As used herein, “optimized” refers to a polynucleotide that is genetically engineered to increase its expression in a given

species. To provide optimized polynucleotides coding for CPV polypeptides, the DNA sequence of the CPV protein gene can be modified to 1) comprise codons preferred by highly expressed genes in a particular species; 2) comprise an A+T or G+C content in nucleotide base composition to that substantially found in said species; 3) form an initiation sequence of said species; or 4) eliminate sequences that cause destabilization, inappropriate polyadenylation, degradation and termination of RNA, or that form secondary structure hairpins or RNA splice sites. Increased expression of CPV protein in said species can be achieved by utilizing the distribution frequency of codon usage in eukaryotes and prokaryotes, or in a particular species. The term “frequency of preferred codon usage” refers to the preference exhibited by a specific host cell in usage of nucleotide codons to specify a given amino acid. There are 20 natural amino acids, most of which are specified by more than one codon. Therefore, all degenerate nucleotide sequences are included in the disclosure as long as the amino acid sequence of the CPV polypeptide encoded by the nucleotide sequence is functionally unchanged.

[0064] The sequence identity between two amino acid sequences may be established by the NCBI (National Center for Biotechnology Information) pairwise blast and the blosum62 matrix, using the standard parameters (see, e.g., the BLAST or BLASTX algorithm available on the "National Center for Biotechnology Information" (NCBI, Bethesda, Md., USA) server, as well as in Altschul *et al.*; and thus, this document speaks of using the algorithm or the BLAST or BLASTX and BLOSUM62 matrix by the term “blasts”).

[0065] The “identity” with respect to sequences can refer to the number of positions with identical nucleotides or amino acids divided by the number of nucleotides or amino acids in the shorter of the two sequences wherein alignment of the two sequences can be determined in accordance with the Wilbur and Lipman algorithm (Wilbur and Lipman), for instance, using a window size of 20 nucleotides, a word length of 4 nucleotides, and a gap penalty of 4, and computer-assisted analysis and interpretation of the sequence data including alignment can be conveniently performed using commercially available programs (e.g., Intelligenetics™ Suite, Intelligenetics Inc. CA). When RNA sequences are said to be similar, or have a degree of sequence identity or homology with DNA sequences, thymidine (T) in the DNA sequence is considered equal to uracil (U) in the RNA sequence. Thus, RNA sequences are within the scope of the invention and can be derived from DNA sequences, by thymidine (T) in the DNA sequence being considered equal to uracil (U) in RNA sequences.

[0066] The sequence identity or sequence similarity of two amino acid sequences, or the sequence identity between two nucleotide sequences can be determined using Vector NTI software package (Invitrogen, 1600 Faraday Ave., Carlsbad, CA).

[0067] The following documents provide algorithms for comparing the relative identity or homology of sequences, and additionally or alternatively with respect to the foregoing, the teachings in these references can be used for determining percent homology or identity: Needleman SB and Wunsch CD; Smith TF and Waterman MS; Smith TF, Waterman MS and Sadler JR; Feng DF and Dolittle RF; Higgins DG and Sharp PM; Thompson JD, Higgins DG and Gibson TJ; and, Devereux J, Haeberlie P and Smithies O. And, without undue experimentation, the skilled artisan can consult with many other programs or references for determining percent homology.

[0068] Hybridization reactions can be performed under conditions of different "stringency." Conditions that increase stringency of a hybridization reaction are well known. See for example, "Molecular Cloning: A Laboratory Manual", second edition (Sambrook et al., 1989).

[0069] The invention further encompasses the CPV polynucleotides contained in a vector molecule or an expression vector and operably linked to a promoter element and optionally to an enhancer.

[0070] A "vector" refers to a recombinant DNA or RNA plasmid or virus that comprises a heterologous polynucleotide to be delivered to a target cell, either *in vitro* or *in vivo*. The heterologous polynucleotide may comprise a sequence of interest for purposes of prevention or therapy, and may optionally be in the form of an expression cassette. As used herein, a vector needs not be capable of replication in the ultimate target cell or subject. The term includes cloning vectors and viral vectors.

[0071] The term "recombinant" means a polynucleotide semisynthetic, or synthetic origin which either does not occur in nature or is linked to another polynucleotide in an arrangement not found in nature.

[0072] "Heterologous" means derived from a genetically distinct entity from the rest of the entity to which it is being compared. For example, a polynucleotide may be placed by genetic engineering techniques into a plasmid or vector derived from a different source, and is a heterologous polynucleotide. A promoter removed from its native coding sequence and operatively linked to a coding sequence other than the native sequence is a heterologous promoter.

[0073] The present invention relates to ovine, bovine, caprine and porcine vaccines or pharmaceutical or immunological compositions which may comprise an effective amount of a recombinant CPV antigens and a pharmaceutically or veterinarily acceptable carrier, adjuvant, excipient, or vehicle.

[0074] The subject matter described herein is directed in part, to compositions and methods related to the CPV antigen prepared in a baculovirus/insect cell expression system that was highly immunogenic and protected animals against challenge from homologous and heterologous CPV strains.

Compositions

[0075] The present invention relates to a CPV vaccine or composition which may comprise an effective amount of a recombinant CPV antigen and a pharmaceutically or veterinarily acceptable carrier, excipient, or vehicle. In one embodiment, the recombinant CPV antigen is expressed by a baculovirus expression vector in insect cells.

[0076] One embodiment of the invention relates to a vaccine or composition comprising CPV empty capsids or CPV VLPs (virus-like particles). The CPV empty capsids or CPV VLPs (virus-like particles) are obtained by expression of the CPV capsid protein.

[0077] The present invention also relates to processes for preparing these vaccines, the use of antigens for producing these vaccines and vaccination methods using them.

[0078] The present invention also relates to nucleotide sequences, in particular cDNA, and to amino acid sequences, modified compared with natural sequences of the virus. The invention also relates to the expression products of the modified nucleotide sequences and to the CPV antigens and virus incorporating these modifications.

[0079] The present invention encompasses any CPV polypeptide, antigen, epitope or immunogen that elicits an immunogenic response in an animal, such as an ovine, bovine, caprine or swine. The CPV polypeptide, antigen, epitope or immunogen may be any CPV polypeptide, antigen, epitope or immunogen, such as, but not limited to, a protein, peptide or fragment thereof, that elicits, induces or stimulates a response in an animal, such as canine.

[0080] In an embodiment wherein the CPV immunological composition or vaccine is a recombinant immunological composition or vaccine, the composition or vaccine comprising a recombinant vector and is non-adjuvanted, and may optionally comprise a pharmaceutical or veterinary acceptable excipient, carrier or vehicle; the recombinant vector is a baculovirus

expression vector which may comprise a polynucleotide encoding a CPV polypeptide, antigen, epitope or immunogen. The CPV polypeptide, antigen, epitope or immunogen, may be capsid protein and any fragment thereof.

[0081] In one embodiment, the nucleic acid molecule encoding one or more CPV antigen(s) is a cDNA encoding a CPV capsid protein. In another embodiment, the nucleic acid molecule encoding one or more CPV antigen(s) is a cDNA encoding a fragment of the CPV capsid protein.

[0082] In another embodiment, the CPV antigen may be derived from CPV strain 100869-1.

[0083] The present invention relates to a CPV composition or vaccine which may comprise an effective amount of a recombinant CPV antigen. The CPV composition or vaccine does not contain an adjuvant. The CPV composition or vaccine may optionally contain a pharmaceutically or veterinarily acceptable carrier, excipient, or vehicle.

[0084] The invention further encompasses the CPV polynucleotides contained in a vector molecule or an expression vector and operably linked to a promoter element and optionally to an enhancer.

[0085] In one aspect, the present invention provides CPV polypeptides having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10, and variants or fragments thereof.

[0086] In another aspect, the present invention provides a polypeptide having at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, 96%, 97%, 98% or 99% sequence identity to an antigenic polypeptide of the invention, particularly to the polypeptides having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

[0087] In yet another aspect, the present invention provides fragments and variants of the CPV polypeptides identified above (SEQ ID NO: 1, 3, 4, 6, or 8-10) which may readily be prepared by one of skill in the art using well-known molecular biology techniques.

[0088] Variants are homologous polypeptides having an amino acid sequence at least 75%, 80%, 85%, 90%, 95%, 96%, 97%, 98%, or 99% identity to the amino acid sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

[0089] An immunogenic fragment of a CPV polypeptide includes at least 8, 10, 15, or 20 consecutive amino acids, at least 21 amino acids, at least 23 amino acids, at least 25 amino acids, or at least 30 amino acids of a CPV polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10, or variants thereof. In another embodiment, a fragment of a CPV polypeptide includes a specific antigenic epitope found on a full-length CPV polypeptide. However, the

skilled person will understand that a sufficient portion of the CPV polypeptide must be present to enable formation of CPV VLPs.

[0090] In another aspect, the present invention provides a polynucleotide encoding a CPV polypeptide, such as a polynucleotide encoding a polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10. In yet another aspect, the present invention provides a polynucleotide encoding a polypeptide having at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, 96%, 97%, 98% or 99% sequence identity to a polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10, or a conservative variant, an allelic variant, a homolog or an immunogenic fragment comprising at least eight or at least ten consecutive amino acids of one of these polypeptides, or a combination of these polypeptides.

[0091] In another aspect, the present invention provides a polynucleotide having a nucleotide sequence as set forth in SEQ ID NO: 2, 5, 7, 11 or 12, or a variant thereof. In yet another aspect, the present invention provides a polynucleotide having at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 95%, 96%, 97%, 98%, or 99% sequence identity to one of a polynucleotide having a sequence as set forth in SEQ ID NO: 2, 5, 7, 11 or 12, or a variant thereof.

[0092] The polynucleotides of the invention may comprise additional sequences, such as additional encoding sequences within the same transcription unit, controlling elements such as promoters, ribosome binding sites, 5'UTR, 3'UTR, transcription terminators, polyadenylation sites, additional transcription units under control of the same or a different promoter, sequences that permit cloning, expression, homologous recombination, and transformation of a host cell, and any such construct as may be desirable to provide embodiments of this invention.

[0093] Elements for the expression of a CPV polypeptide, antigen, epitope or immunogen are advantageously present in an inventive vector. In minimum manner, this comprises, consists essentially of, or consists of an initiation codon (ATG), a stop codon and a promoter, and optionally also a polyadenylation sequence for certain vectors such as plasmid and certain viral vectors, e.g., viral vectors other than poxviruses. When the polynucleotide encodes a polyprotein fragment, e.g. a CPV peptide, advantageously, in the vector, an ATG is placed at 5' of the reading frame and a stop codon is placed at 3'. Other elements for controlling expression may be present, such as enhancer sequences, stabilizing sequences, such as intron and signal sequences permitting the secretion of the protein.

[0094] The present invention also relates to preparations comprising vectors, such as expression vectors, e.g., therapeutic compositions. The preparations can comprise one or more vectors, e.g., expression vectors, such as *in vivo* expression vectors, comprising and expressing one or more CPV polypeptides, antigens, epitopes or immunogens. In one embodiment, the vector contains and expresses a polynucleotide that comprises, consists essentially of, or consists of a polynucleotide coding for (and advantageously expressing) a CPV antigen, epitope or immunogen, in a pharmaceutically or veterinarily acceptable carrier, excipient or vehicle. Thus, according to an embodiment of the invention, the other vector or vectors in the preparation comprises, consists essentially of or consists of a polynucleotide that encodes, and under appropriate circumstances the vector expresses one or more other proteins of a CPV polypeptide, antigen, epitope or immunogen, or a fragment thereof.

[0095] According to another embodiment, the vector or vectors in the preparation comprise, or consist essentially of, or consist of polynucleotide(s) encoding one or more proteins or fragment(s) thereof of a CPV polypeptide, antigen, epitope or immunogen, the vector or vectors expressing the polynucleotide(s). In another embodiment, the preparation comprises one, two, or more vectors comprising polynucleotides encoding and expressing, advantageously *in vivo*, a CPV polypeptide, antigen, fusion protein or an epitope thereof.

[0096] According to a yet further embodiment of the invention, the expression vector is a plasmid vector or a DNA plasmid vector, in particular an *in vivo* expression vector. In a specific, non-limiting example, the pVR1020 or 1012 plasmid (VICAL Inc.; Luke et al., 1997; Hartikka et al., 1996, see, e.g., U.S. Patent Nos. 5,846,946 and 6,451,769) can be utilized as a vector for the insertion of a polynucleotide sequence. The pVR1020 plasmid is derived from pVR1012 and contains the human tPA signal sequence. In one embodiment the human tPA signal comprises from amino acid M(1) to amino acid S(23) in Genbank under the accession number HUMTPA14. In another specific, non-limiting example, the plasmid utilized as a vector for the insertion of a polynucleotide sequence can contain the signal peptide sequence of equine IGF1 from amino acid M(24) to amino acid A(48) in Genbank under the accession number U28070. Additional information on DNA plasmids which may be consulted or employed in the practice are found, for example, in U.S. Patent Nos. 6,852,705; 6,818,628; 6,586,412; 6,576,243; 6,558,674; 6,464,984; 6,451,770; 6,376,473 and 6,221,362.

[0097] The term plasmid covers any DNA transcription unit comprising a polynucleotide according to the invention and the elements necessary for its *in vivo* expression in a cell or cells of the desired host or target; and, in this regard, it is noted that a supercoiled or non-

supercoiled, circular plasmid, as well as a linear form, are intended to be within the scope of the invention.

[0098] Each plasmid comprises or contains or consists essentially of, in addition to the polynucleotide encoding a CPV antigen, epitope or immunogen, optionally fused with a heterologous peptide sequence, variant, analog or fragment, operably linked to a promoter or under the control of a promoter or dependent upon a promoter. In general, it is advantageous to employ a strong promoter functional in eukaryotic cells. The strong promoter may be, but not limited to, the immediate early cytomegalovirus promoter (CMV-IE) of human or murine origin, or optionally having another origin such as the rat or guinea pig, the Super promoter (Ni, M. et al., Plant J. 7, 661-676, 1995.). The CMV-IE promoter can comprise the actual promoter part, which may or may not be associated with the enhancer part. Reference can be made to EP-A-260 148, EP-A-323 597, U.S. Patents Nos. 5,168,062, 5,385,839, and 4,968,615, as well as to PCT Application No WO87/03905. The CMV-IE promoter is advantageously a human CMV-IE (Boshart et al., 1985) or murine CMV-IE.

[0099] In more general terms, the promoter has either a viral, a plant, or a cellular origin. A strong viral promoter other than CMV-IE that may be usefully employed in the practice of the invention is the early/late promoter of the SV40 virus or the LTR promoter of the Rous sarcoma virus. A strong cellular promoter that may be usefully employed in the practice of the invention is the promoter of a gene of the cytoskeleton, such as e.g. the desmin promoter (Kwissa et al., 2000), or the actin promoter (Miyazaki et al., 1989).

[0100] The plasmids may comprise other expression control elements. It is particularly advantageous to incorporate stabilizing sequence(s), e.g., intron sequence(s), for example, maize alcohol dehydrogenase intron (Callis et al. Genes & Dev.1(10):1183-1200, Dec. 1987), the first intron of the hCMV-IE (PCT Application No. WO1989/01036), the intron II of the rabbit β-globin gene (van Ooyen et al., 1979). In another embodiment, the plasmids may comprise 3' UTR. The 3' UTR may be, but not limited to, *agrobacterium* nopaline synthase (Nos) 3' UTR (Nopaline synthase: transcript mapping and DNA sequence. Depicker, A. et al. J. Mol. Appl. Genet., 1982; Bevan, NAR, 1984, 12(22): 8711-8721).

[0101] As to the polyadenylation signal (polyA) for the plasmids and viral vectors other than poxviruses, use can more be made of the poly(A) signal of the bovine growth hormone (bGH) gene (see U.S. 5,122,458), or the poly(A) signal of the rabbit β-globin gene or the poly(A) signal of the SV40 virus.

[0102] A "host cell" denotes a prokaryotic or eukaryotic cell that has been genetically altered, or is capable of being genetically altered by administration of an exogenous polynucleotide, such as a recombinant plasmid or vector. When referring to genetically altered cells, the term refers both to the originally altered cell and to the progeny thereof.

[0103] In one embodiment, the recombinant CPV antigen is expressed in insect cells.

[0104] In one particular embodiment, the CPV antigen is expressed in SF9 cells.

Methods of Use

[0105] In an embodiment, the subject matter disclosed herein is directed to a method of vaccinating an ovine, bovine, caprine, or swine comprising administering to the ovine, bovine, caprine, or swine an effective amount of a vaccine which may comprise an effective amount of a recombinant CPV antigen and a pharmaceutically or veterinarily acceptable carrier, excipient, or vehicle.

[0106] In one embodiment of the present invention, the method comprises a single administration of a vaccine composition formulated with an emulsion according to the invention. For example, in one embodiment, the immunological or vaccine composition comprises baculovirus expressed CPV antigens, including polypeptides and VLPs (virus-like particles) or empty capsids. Electron microscopy indicates the insect cells transformed with baculovirus expression vectors produce CPV VLPs or CPV empty capsids, and so immunological or vaccine compositions according to the instant invention encompass those comprising CPV VLPs or CPV empty capsids.

[0107] In an embodiment, the subject matter disclosed herein is directed to a method of vaccinating an ovine, bovine, caprine, or swine comprising administering to the ovine, bovine, caprine, or swine the CPV antigen produced by a baculovirus vector in insect cells.

[0108] In an embodiment, the subject matter disclosed herein is directed to a method of eliciting an immune response comprising administering to the ovine, bovine, caprine, or swine a vaccine comprising the CPV antigen produced by a baculovirus vector in insect cells.

[0109] In an embodiment, the subject matter disclosed herein is directed to a method of preparing a vaccine or composition comprising isolating a CPV antigen produced by a baculovirus vector in insect cells and optionally combining with a pharmaceutically or veterinarily acceptable carrier, excipient or vehicle.

[0110] Both homologous and heterologous CPV strains are used for challenge to test the efficacy of the vaccine. The administering may be subcutaneously or intramuscularly. The administering may be needle free (for example, Bioject).

[0111] In one embodiment of the invention, a prime-boost regimen can be employed, which is comprised of at least one primary administration and at least one booster administration using at least one common polypeptide, antigen, epitope or immunogen. Typically the immunological composition or vaccine used in primary administration is different in nature from those used as a booster. However, it is noted that the same composition can be used as the primary administration and the boost. This administration protocol is called "prime-boost".

[0112] A prime-boost according to the present invention can include a recombinant viral vector is used to express a CPV coding sequence or fragments thereof encoding an antigenic polypeptide or fragment or variant thereof. Specifically, the viral vector can express a CPV gene or fragment thereof that encodes an antigenic polypeptide. Viral vector contemplated herein includes, but not limited to, poxvirus [e.g., vaccinia virus or attenuated vaccinia virus, avipox virus or attenuated avipox virus (e.g., canarypox, fowlpox, dovepox, pigeonpox, quailpox, ALVAC, TROVAC; see e.g., US 5,505,941, US 5,494,8070), raccoonpox virus, swinepox virus, etc.], adenovirus (e.g., human adenovirus, canine adenovirus), herpesvirus (e.g. canine herpesvirus, herpesvirus of turkey, Marek's disease virus, infectious laryngotracheitis virus, feline herpesvirus, laryngotracheitis virus (ILTV), bovine herpesvirus, swine herpesvirus), baculovirus, retrovirus, etc. In another embodiment, the avipox expression vector may be a canarypox vector, such as, ALVAC. In yet another embodiment, the avipox expression vector may be a fowlpox vector, such as, TROVAC. The CPV antigen of the invention to be expressed is inserted under the control of a specific poxvirus promoter, e.g., the entomopoxvirus *Amsacta moorei* 42K promoter (Barcena, Lorenzo et al. 2000), the vaccinia promoter 7.5 kDa (Cochran et al., 1985), the vaccinia promoter I3L (Riviere et al., 1992), the vaccinia promoter HA (Shida, 1986), the cowpox promoter ATI (Funahashi et al., 1988), the vaccinia promoter H6 (Taylor et al., 1988b; Guo et al., 1989; Perkus et al., 1989), *inter alia*.

[0113] In another aspect of the prime-boost protocol of the invention, a composition comprising the CPV antigen of the invention is administered followed by the administration of vaccine or composition comprising a recombinant viral vector that contains and expresses the CPV antigen *in vivo*, or an inactivated viral vaccine or composition comprising the CPV antigen, or a DNA plasmid vaccine or composition that contains or expresses the CPV antigen. Likewise, a prime-boost protocol may comprise the administration of vaccine or composition comprising a

recombinant viral vector that contains and expresses a CPV antigen *in vivo*, or an inactivated viral vaccine or composition comprising a CPV antigen, or a DNA plasmid vaccine or composition that contains or expresses a CPV antigen, followed by the administration of a composition comprising the CPV antigen of the invention. It is further noted that both the primary and the secondary administrations may comprise the composition comprising the CPV antigen of the invention.

[0114] A prime-boost protocol comprises at least one prime-administration and at least one boost administration using at least one common polypeptide and/or variants or fragments thereof. The vaccine used in prime-administration may be different in nature from those used as a later booster vaccine. The prime-administration may comprise one or more administrations. Similarly, the boost administration may comprise one or more administrations.

[0115] The dose volume of compositions for target species that are mammals based on viral vectors, e.g., non-poxvirus-viral-vector-based compositions, is generally between about 0.1 to about 5.0 ml, between about 0.1 to about 3.0 ml, and between about 0.5 ml to about 2.5 ml.

[0116] The efficacy of the vaccines may be tested about 2 to 4 weeks after the last immunization by challenging animals, such as feline or canine, with a virulent strain of CPV.

[0117] Further details of these CPV strains may be found on the European Bioinformatics Information (EMBL-EBI) web pages, and all of the associated nucleotide sequences are herein incorporated by reference. The inventors contemplate that all CPV strains, both herein listed, and those yet to be identified, could be expressed according to the teachings of the present disclosure to produce, for example, effective vaccine compositions. Both homologous and heterologous strains are used for challenge to test the efficacy of the vaccines. The animal may be challenged intradermally, subcutaneously, spray, intra-nasally, intra-ocularly, intra-tracheally, and/or orally.

[0118] The prime-boost administrations may be advantageously carried out 1 to 6 weeks apart, for example, about 4 weeks apart. According to one embodiment, a semi-annual booster or an annual booster, advantageously using the viral vector-based vaccine, is also envisaged. The animals are advantageously at least 6 to 8 weeks old at the time of the first administration.

[0119] The compositions comprising the recombinant antigenic polypeptides of the invention used in the prime-boost protocols are not adjuvanted, and may optionally be contained in a pharmaceutically or veterinary acceptable vehicle, diluent or excipient. The protocols of the

invention protect the animal from CPV and/or prevent disease progression in an infected animal.

[0120] It should be understood by one of skill in the art that the disclosure herein is provided by way of example and the present invention is not limited thereto. From the disclosure herein and the knowledge in the art, the skilled artisan can determine the number of administrations, the administration route, and the doses to be used for each injection protocol, without any undue experimentation.

[0121] The present invention contemplates at least one administration to an animal of an efficient amount of the therapeutic composition made according to the invention. The animal may be male, female, pregnant female and newborn. This administration may be via various routes including, but not limited to, intramuscular (IM), intradermal (ID) or subcutaneous (SC) injection or via intranasal or oral administration. The therapeutic composition according to the invention can also be administered by a needleless apparatus (as, for example with a Pigjet, Dermojet, Biojector, Avijet (Merial, GA, USA), Vetjet or Vitajet apparatus (Bioject, Oregon, USA)). Another approach to administering plasmid compositions is to use electroporation (see, e.g. Tollefsen et al., 2002; Tollefsen et al., 2003; Babiuk et al., 2002; PCT Application No. WO99/01158). In another embodiment, the therapeutic composition is delivered to the animal by gene gun or gold particle bombardment.

[0122] In one embodiment, the invention provides for the administration of a therapeutically effective amount of a formulation for the delivery and expression of a CPV antigen or epitope in a target cell. Determination of the therapeutically effective amount is routine experimentation for one of ordinary skill in the art. In one embodiment, the formulation comprises an expression vector comprising a polynucleotide that expresses a CPV antigen or epitope and a pharmaceutically or veterinarily acceptable carrier, vehicle or excipient. In another embodiment, the pharmaceutically or veterinarily acceptable carrier, vehicle or excipient facilitates transfection or other means of transfer of polynucleotides to a host animal and/or improves preservation of the vector or protein in a host.

[0123] In one embodiment, the subject matter disclosed herein provides a detection method for differentiation between infected and vaccinated animals (DIVA).

[0124] It is disclosed herein that the use of the vaccine or composition of the present invention allows the detection of CPV infection in an animal. It is disclosed herein that the use of the

vaccine or composition of the present invention allows the detection of the infection in animals by differentiating between infected and vaccinated animals (DIVA).

Article of Manufacture

[0125] In an embodiment, the subject matter disclosed herein is directed to a kit for performing a method of eliciting or inducing an immune response which may comprise any one of the recombinant CPV immunological compositions or vaccines, or inactivated CPV immunological compositions or vaccines, recombinant CPV viral compositions or vaccines, and instructions for performing the method.

[0126] Another embodiment of the invention is a kit for performing a method of inducing an immunological or protective response against CPV in an animal comprising a composition or vaccine comprising a CPV antigen of the invention and a recombinant CPV viral immunological composition or vaccine, and instructions for performing the method of delivery in an effective amount for eliciting an immune response in the animal.

[0127] Another embodiment of the invention is a kit for performing a method of inducing an immunological or protective response against CPV in an animal comprising a composition or vaccine comprising a CPV antigen of the invention and an inactivated CPV immunological composition or vaccine, and instructions for performing the method of delivery in an effective amount for eliciting an immune response in the animal.

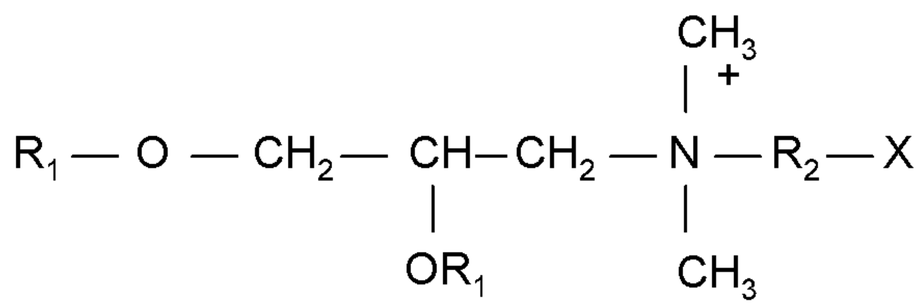
[0128] Yet another aspect of the present invention relates to a kit for prime-boost vaccination according to the present invention as described above. The kit may comprise at least two vials: a first vial containing a vaccine or composition for the prime-vaccination according to the present invention, and a second vial containing a vaccine or composition for the boost-vaccination according to the present invention. The kit may advantageously contain additional first or second vials for additional primo-vaccinations or additional boost-vaccinations.

[0129] The following embodiments are encompassed by the invention. In an embodiment, a composition comprising a CPV antigen or fragment or variant thereof and a pharmaceutical or veterinarily acceptable carrier, excipient, or vehicle is disclosed. In another embodiment, the composition described above wherein the CPV antigen or fragment or variant thereof comprises an immunogenic fragment comprising at least 15 amino acids of a CPV antigen is disclosed. In an embodiment, the above compositions wherein the CPV antigen or fragment or variant thereof is partially purified are disclosed. In an embodiment, the above compositions wherein the CPV antigen or fragment or variant thereof is substantially purified are disclosed.

[0130] In an embodiment, the above compositions wherein the CPV antigen or fragment or variant thereof is a CPV polypeptide are disclosed. In an embodiment, the above compositions wherein the CPV polypeptide is a capsid protein or a fragment thereof are disclosed. In an embodiment, the above compositions wherein the CPV antigen or fragment or variant thereof has at least 80% sequence identity to the sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10 are disclosed. In one embodiment, the above compositions wherein the CPV antigen is encoded by a polynucleotide having at least 70% sequence identity to the sequence as set forth in SEQ ID NO: 2, 5, 7, 11 or 12 are disclosed. In another embodiment, a method of vaccinating an animal susceptible to CPV comprising administering the compositions above to the animal is disclosed. In an embodiment, a method of vaccinating an animal susceptible to CPV comprising a prime-boost regime is disclosed. In an embodiment, a substantially purified antigenic polypeptide expressed in insect cells, wherein the polypeptide comprises: an amino acid sequence having at least 80% sequence identity to a polypeptide having the sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10 is disclosed. In any embodiment the animal is preferably a feline or canine. In one embodiment, a method of diagnosing CPV infection in an animal is disclosed. In yet another embodiment, a kit for prime-boost vaccination comprising at least two vials, wherein a first vial containing the composition of the present invention, and a second vial containing a composition for the boost-vaccination comprising a composition comprising a recombinant viral vector, or a composition comprising an inactivated viral composition, or a DNA plasmid composition that contains or expresses the CPV antigen is disclosed.

[0131] The pharmaceutically or veterinarily acceptable carriers or vehicles or excipients are well known to the one skilled in the art. For example, a pharmaceutically or veterinarily acceptable carrier or vehicle or excipient can be a 0.9% NaCl (e.g., saline) solution or a phosphate buffer. Other pharmaceutically or veterinarily acceptable carrier or vehicle or excipients that can be used for methods of this invention include, but are not limited to, poly-(L-glutamate) or polyvinylpyrrolidone. The pharmaceutically or veterinarily acceptable carrier or vehicle or excipients may be any compound or combination of compounds facilitating the administration of the vector (or protein expressed from an inventive vector *in vitro*); advantageously, the carrier, vehicle or excipient may facilitate transfection and/or improve preservation of the vector (or protein). Doses and dose volumes are herein discussed in the general description and can also be determined by the skilled artisan from this disclosure read in conjunction with the knowledge in the art, without any undue experimentation.

[0132] The cationic lipids containing a quaternary ammonium salt which are advantageously but not exclusively suitable for plasmids, are advantageously those having the following formula:



in which R1 is a saturated or unsaturated straight-chain aliphatic radical having 12 to 18 carbon atoms, R2 is another aliphatic radical containing 2 or 3 carbon atoms and X is an amine or hydroxyl group, e.g. the DMRIE. In another embodiment the cationic lipid can be associated with a neutral lipid, e.g. the DOPE.

[0133] Among these cationic lipids, preference is given to DMRIE (N-(2-hydroxyethyl)-N,N-dimethyl-2,3-bis(tetradecyloxy)-1-propane ammonium; WO96/34109), advantageously associated with a neutral lipid, advantageously DOPE (dioleoyl-phosphatidyl-ethanol amine; Behr, 1994), to form DMRIE-DOPE.

[0134] Advantageously, the plasmid mixture with the adjuvant is formed extemporaneously and advantageously contemporaneously with administration of the preparation or shortly before administration of the preparation; for instance, shortly before or prior to administration, the plasmid-adjuvant mixture is formed, advantageously so as to give enough time prior to administration for the mixture to form a complex, e.g. between about 10 and about 60 minutes prior to administration, such as approximately 30 minutes prior to administration.

[0135] When DOPE is present, the DMRIE:DOPE molar ratio is advantageously about 95: about 5 to about 5: about 95, more advantageously about 1: about 1, e.g., 1:1.

[0136] The DMRIE or DMRIE-DOPE adjuvant:plasmid weight ratio can be between about 50: about 1 and about 1: about 10, such as about 10: about 1 and about 1:about 5, and about 1: about 1 and about 1: about 2, e.g., 1:1 and 1:2.

[0137] In another embodiment, pharmaceutically or veterinarily acceptable carrier, excipient, adjuvant, or vehicle may be a water-in-oil emulsion. Examples of suitable water-in-oil emulsions include oil-based water-in-oil vaccinal emulsions which are stable and fluid at 4°C containing: from 6 to 50 v/v% of an antigen-containing aqueous phase, preferably from 12 to 25 v/v%, from 50 to 94 v/v% of an oil phase containing in total or in part a non-metabolizable oil (e.g., mineral oil such as paraffin oil) and/or metabolizable oil (e.g., vegetable oil, or fatty acid, polyol or

alcohol esters), from 0.2 to 20 p/v% of surfactants, preferably from 3 to 8 p/v%, the latter being in total or in part, or in a mixture either polyglycerol esters, said polyglycerol esters being preferably polyglycerol (poly)ricinoleates, or polyoxyethylene ricin oils or else hydrogenated polyoxyethylene ricin oils. Examples of surfactants that may be used in a water-in-oil emulsion include ethoxylated sorbitan esters (e.g., polyoxyethylene (20) sorbitan monooleate (TWEEN 80®), available from AppliChem, Inc., Cheshire, CT) and sorbitan esters (e.g., sorbitan monooleate (SPAN 80®), available from Sigma Aldrich, St. Louis, MO). In addition, with respect to a water-in-oil emulsion, see also US Patent No. 6,919,084, e.g., Example 8 thereof, incorporated herein by reference. In some embodiments, the antigen-containing aqueous phase comprises a saline solution comprising one or more buffering agents. An example of a suitable buffering solution is phosphate buffered saline. In an advantageous embodiment, the water-in-oil emulsion may be a water/oil/water (W/O/W) triple emulsion (U.S. Patent No. 6,358,500). Examples of other suitable emulsions are described in U.S. Patent No. 7,371,395.

[0138] The immunological compositions and vaccines according to the invention may comprise or consist essentially of one or more adjuvants. Suitable adjuvants for use in the practice of the present invention are (1) polymers of acrylic or methacrylic acid, maleic anhydride and alkenyl derivative polymers, (2) immunostimulating sequences (ISS), such as oligodeoxyribonucleotide sequences having one or more non-methylated CpG units (Klinman et al., 1996; WO98/16247), (3) an oil in water emulsion, such as the SPT emulsion described on page 147 of "Vaccine Design, The Subunit and Adjuvant Approach" published by M. Powell, M. Newman, Plenum Press 1995, and the emulsion MF59 described on page 183 of the same work, (4) cation lipids containing a quaternary ammonium salt, e.g., DDA (5) cytokines, (6) aluminum hydroxide or aluminum phosphate, (7) saponin or (8) other adjuvants discussed in any document cited and incorporated by reference into the instant application, or (9) any combinations or mixtures thereof.

[0139] The oil in water emulsion (3), which is especially appropriate for viral vectors, can be based on: light liquid paraffin oil (European pharmacopoeia type), isoprenoid oil such as squalane, squalene, oil resulting from the oligomerization of alkenes, e.g. isobutene or decene, esters of acids or alcohols having a straight-chain alkyl group, such as vegetable oils, ethyl oleate, propylene glycol, di(caprylate/caprate), glycerol tri(caprylate/caprate) and propylene glycol dioleate, or esters of branched, fatty alcohols or acids, especially isostearic acid esters.

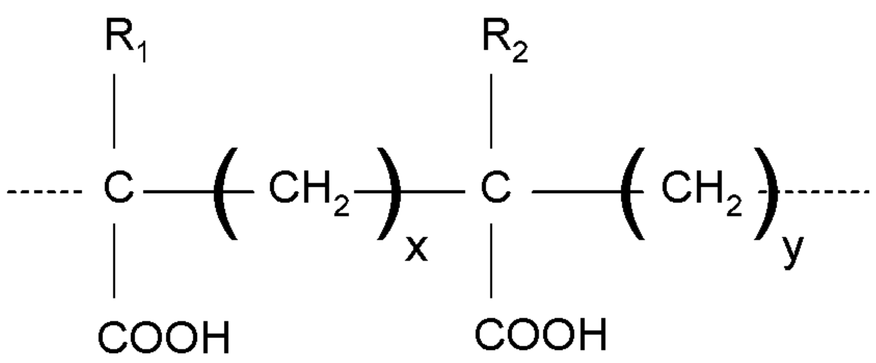
[0140] The oil is used in combination with emulsifiers to form an emulsion. The emulsifiers may be nonionic surfactants, such as: esters of on the one hand sorbitan, mannide (e.g.

anhydromannitol oleate), glycerol, polyglycerol or propylene glycol and on the other hand oleic, isostearic, ricinoleic or hydroxystearic acids, said esters being optionally ethoxylated, or polyoxypropylene-polyoxyethylene copolymer blocks, such as Pluronic, e.g., L121.

[0141] Among the type (1) adjuvant polymers, preference is given to polymers of crosslinked acrylic or methacrylic acid, especially crosslinked by polyalkenyl ethers of sugars or polyalcohols. These compounds are known under the name carbomer (Pharmeuropa, vol. 8, no. 2, June 1996). One skilled in the art can also refer to U.S. Patent No. 2,909,462, which provides such acrylic polymers crosslinked by a polyhydroxyl compound having at least three hydroxyl groups, preferably no more than eight such groups, the hydrogen atoms of at least three hydroxyl groups being replaced by unsaturated, aliphatic radicals having at least two carbon atoms. The preferred radicals are those containing 2 to 4 carbon atoms, e.g. vinyls, allyls and other ethylenically unsaturated groups. The unsaturated radicals can also contain other substituents, such as methyl. Products sold under the name Carbopol (BF Goodrich, Ohio, USA) are especially suitable. They are crosslinked by allyl saccharose or by allyl pentaerythritol. Among them, reference is made to Carbopol 974P, 934P and 971P.

[0142] As to the maleic anhydride-alkenyl derivative copolymers, preference is given to EMA (Monsanto), which are straight-chain or crosslinked ethylene-maleic anhydride copolymers and they are, for example, crosslinked by divinyl ether. Reference is also made to J. Fields et al., 1960.

[0143] With regard to structure, the acrylic or methacrylic acid polymers and EMA are preferably formed by basic units having the following formula:



in which: R1 and R2, which can be the same or different, represent H or CH3; x = 0 or 1, preferably x = 1; y = 1 or 2, with x + y = 2.

For EMA, x = 0 and y = 2 and for carbomers x = y = 1.

[0144] These polymers are soluble in water or physiological salt solution (20 g/l NaCl) and the pH can be adjusted to 7.3 to 7.4, e.g., by soda (NaOH), to provide the adjuvant solution in which the expression vector(s) can be incorporated. The polymer concentration in the final immunological or vaccine composition can range between about 0.01 to about 1.5% w/v, about 0.05 to about 1% w/v, and about 0.1 to about 0.4% w/v.

[0145] The cytokine or cytokines (5) can be in protein form in the immunological or vaccine composition, or can be co-expressed in the host with the immunogen or immunogens or epitope(s) thereof. Preference is given to the co-expression of the cytokine or cytokines, either by the same vector as that expressing the immunogen or immunogens or epitope(s) thereof, or by a separate vector thereof.

[0146] The invention comprehends preparing such combination compositions; for instance by admixing the active components, advantageously together and with a carrier, cytokine, and/or diluent.

[0147] Cytokines that may be used in the present invention include, but are not limited to, granulocyte colony stimulating factor (G-CSF), granulocyte/macrophage colony stimulating factor (GM-CSF), interferon α (IFNα), interferon β (IFNβ), interferon γ, (IFNγ), interleukin-1α (IL-1α), interleukin-1β (IL-1β), interleukin-2 (IL-2), interleukin-3 (IL-3), interleukin-4 (IL-4), interleukin-5 (IL-5), interleukin-6 (IL-6), interleukin-7 (IL-7), interleukin-8 (IL-8), interleukin-9 (IL-9), interleukin-10 (IL-10), interleukin-11 (IL-11), interleukin-12 (IL-12), tumor necrosis factor α (TNFα), tumor necrosis factor β (TNFβ), polyinosinic and polycytidylic acid, cytidine–phosphate–guanosine oligodeoxynucleotides (CpG ODN), and transforming growth factor β (TGFβ). It is understood that cytokines can be co-administered and/or sequentially administered with the immunological or vaccine composition of the present invention. Thus, for instance, the vaccine of the instant invention can also contain an exogenous nucleic acid molecule that expresses *in vivo* a suitable cytokine, e.g., a cytokine matched to this host to be vaccinated or in which an immunological response is to be elicited (for instance, a bovine cytokine for preparations to be administered to bovines).

[0148] In the case of immunological composition and/or vaccine based on a baculovirus/insect cell-expressed polypeptides, a dose may include, about 1 μg to about 2000 μg, about 50 μg to about 1000 μg, and from about 100 μg to about 500 μg of CPV antigen, epitope or immunogen. The dose may include about 10^2 to about 10^{20} VLPs, about 10^3 to about 10^{20}, about 10^4 to about 10^{20}. The dose volumes can be between about 0.1 and about 10 ml, between about 0.2 and about 5 ml. In general, the skilled person is aware of many dosing strategies, and will be able to optimize dosing without the exercise of non-routing work.

[0149] In an aspect, the invention provides a combination vaccine comprising a virus-like particle (VLP) component and a modified-live virus (MLV) component, wherein both the VLP

and the MLV are directed against the same pathogen or disease, and wherein the combination vaccine overcomes maternally-derived antibodies (MDA).

[0150] In some embodiments, the combination vaccine provides protective immunity with a single dose.

[0151] In some embodiments, the pathogen or disease is canine parvovirus (CPV).

[0152] In some embodiments, the pathogen or disease is foot-and-mouth disease virus (FMDV).

[0153] In some embodiments, the VLP component of the combination comprises at least at least 10% CPV VLPs (w/w) as a function of total protein content.

[0154] In some embodiments, the VLP component comprises at least 20% CPV VLPs (w/w).

[0155] In some embodiments, the CPV VLP is expressed by a baculovirus vector in insect cells.

[0156] In some embodiments, the CPV VLP comprises at least one CPV capsid protein.

[0157] In some embodiments, the CPV VLP comprises a CPV polypeptide having the sequence as set forth in SEQ ID NO: 1, 3, 4, 6, 8, 9 or 10; or, the CPV VLP comprises a CPV polypeptide having at least 90% identity a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, 8, 9 or 10.

[0158] In some embodiments, the CPV VLP comprises a CPV polypeptide encoded by a polynucleotide having the sequence as set forth in SEQ ID NO: 2, 5 or 7; or, the CPV VLP comprises a CPV polypeptide encoded by a polynucleotide having at least 90% identity to a sequence as set forth in SEQ ID NO: 2, 5 or 7.

[0159] In some embodiments, the combination vaccine is not adjuvanted and optionally comprises a pharmaceutically or veterinarily acceptable carrier, excipient, or vehicle.

[0160] In another aspect, the invention provides a plasmid useful for producing CPV VLP, comprising a polynucleotide encoding a CPV antigen having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10, or a polynucleotide sequence having at least 90% identity to a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

[0161] In some embodiments, the polynucleotide comprises or consists of the sequence as set forth in SEQ ID NO: 2, 5, 7, 11 or 12.

[0162] In some embodiments, the plasmid consists of the sequence as set forth in SEQ ID NO:11 or 12.

[0163] In some embodiments, the plasmid is stably transformed into an insect cell, which expresses CPV VLPs.

[0164] In another aspect, the invention provides a substantially purified CPV empty capsid or CPV VLP expressed in insect cells, wherein the CPV empty capsid or VLP comprises a polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10; or, the CPV empty capsid or VLP comprises a polypeptide having at least 90% identity to a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

[0165] In some embodiments, the CPV empty capsid or VLP consists of a polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

[0166] In another aspect, the invention provides a method of eliciting an immune response in an animal against CPV comprising administering to the animal the compositions, vaccines, combination vaccines and VLPS disclosed herein.

[0167] In some embodiments, the immune response protects vaccinates against subsequent exposure to virulent CPV. The exposure may be natural or experimental.

[0168] In some embodiments, the immune response is elicited in the vaccinated animals regardless of the presence in said animals of high levels of maternally-derived antibodies (MDA) against CPV. "High levels" has the ordinary meaning, and generally refers to levels of MDA that impede the ability of prior art vaccines to elicit a strong protective response in MDA-positive animals.

[0169] The invention will now be further described by way of the following non-limiting examples.

EXAMPLES

[0170] Unless otherwise described, construction of DNA inserts, plasmids and recombinant viral or baculovirus vectors was carried out using the standard molecular biology techniques described by J. Sambrook *et al.* (Molecular Cloning: A Laboratory Manual, 2nd Edition, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1989).

Example 1 Construction and expression of CPV capsid antigens in baculovirus/insect cells system

[0171] Objective: Generate a pVL1393-based transfer plasmid encoding the CPV capsid protein of CPV (canine parvovirus, strain *Souriou* serotype 2c) optimized for insect cells and generation of the recombinant baculovirus BacMEB072 in order to express virus like particles (VLP). The

reference sequence was strain *Souriou* 2c (Merial), having the designation Genbank BAD34656 / Swissprot P61826 (SEQ ID NO: 1).

[0172] The CPV capsid gene (1755 bp) encodes a 584 amino acid polypeptide (containing no signal peptide). The sequence encoding the CPV VP2 protein (SEQ ID NO: 1) was cloned and the corresponding DNA sequence was codon-optimized (SEQ ID NO: 5) for insect cells. Potential functional domains are shown in Table 1 below.

Table 1 Potential functional domains are the following (according to Swiss-prot annotation on P61826)

Putative domains	From to (or position)	Length
Signal sequence	no	
mature chain VP2	1-584	584
N-glycosylation	25-47-64-180-443-505-517	
N-glycosylation sites	490-494	

[0173] Generation of plasmid pMEB072. The CPV capsid optimized for insect expression (SEQ ID NO: 1) was cloned into commercial plasmid pVL1393 (Pharmingen) using the XbaI and Bam HI sites of both the vector and insert to generate the expression plasmid pMEB072.

[0174] Generation of recombinant baculovirus BacMEB072. The baculovirus vector used was AcNPV modified by a lethal deletion that is only rescued through homologous recombination (BaculoGold DNA, Pharmingen). Plasmid pMEB072 was used to generate a recombinant baculovirus, encoding CPV capsid gene strain *Souriou* serotype 2c under control of polyhedrin promoter, by homologous recombination. *Spodoptera frugiperda* (Sf) 9 insect cells were co-transfected with plasmid pMEB072 and Bsu36I triple-cut linearized AcNPV DNA, according to manufacturer's protocol (Baculogold, Pharmingen). Recombinant baculovirus from co-transfection supernatant were plaque purified twice. Five clones were amplified (passage 1) at 28°C at a 25 cm^2 monolayer flask scale. Infected cells and supernatants were analysed for CPV capsid expression by Dot Blot using monoclonals specific of CPV capsid antigen (CPV103B10A). Clone 1 showed a correct Dot Blot profile. This clone was further amplified (passage 2) at 28°C at a 50mL scale in Erlenmeyer (suspension) at 105 rpm. A third passage (passage 3) at a 200mL scale was performed to obtain virus stock used for protein expression. This virus stock was then titrated by plaque assay. Virus stock was obtained using SF900II media, supplemented with 2% of FCS. After titration recombinant baculovirus stock (Passage 3) was used for protein production in serum free medium.

Expression analysis of baculovirus BacMEB072

Table 2

Plasmid	Size (AA)	PM (kDa)	Signal peptide	Tag	N-glycosylation	Disulfide bridge	location
pMEB062	545	59.2	no	no	10 potential sites	No	secretion

[0175] Insect cells (Sf9) were infected with BacMEB072 at a Multiplicity Of Infection (MOI) of 1 pfu/ml. Insect cells were grown at 105 rpm in Sf900II medium without FCS for 4 days at 28°C. Protein production was analyzed by submitting whole Sf9 lysates and culture supernatant to SDS-PAGE (4-20%, Invitrogen), followed by Dot Blot with monoclonal antibody (CPV103B10A). The solubility of the expressed proteins was studied by lysing the cellular pellets in lysis buffer (50 mM Tris-Hcl pH8, 500 mM NaCl + anti protease), sonication 3X (15 sec at 20% power, 30 sec wait, 15 sec at 20% power; 5 min lysis on ice). Soluble proteins were separated from the insoluble material by centrifugation (30 min at 11,000 rcf at 4°C).

[0176] A band at expected size was expressed in the cell pellet of infected cells lysed and clarified as observed by coomassie staining. The protein accumulated in cells, but was also detected in the soluble fraction after lysis. The identity of VP2 protein was confirmed by Dot Blot using specific monoclonal antibody against CPV capsid (CPV103B10A).

[0177] The electronic microscopy (EM) analysis confirmed correct auto-assembly of the capsid protein into VLPs, which had a diameter of 25-30 nm, and a correct morphology of parvovirus-like virions (FIG. 4). The optimal conditions for VLP production were to use MOI=0.1 and to harvest at 5 days post-infection. Although other conditions are envisioned, these particular conditions yielded a concentration of about 10^{11} VLPs per ml.

Example 2 – production of BacMEB073 containing truncated CPV VP2

[0178] The objective was to generate a pVL1393-based transfer plasmid encoding the truncated VP2 capsid protein of CPV (canine parvovirus, strain Souriou serotype 2c) optimized for mammals, and then to generate the corresponding recombinant baculovirus BacMEB073, expressing the VLP. The 9 N-terminal amino acids (-9AA) were deleted in an effort to enhance VP2 expression without preventing VLP formation (Hurtado et al. Journal of Virology, August 1996). In addition, three amino acids were added (M, L and K) in an effort to improve capsid structure and formation (Gilbert et al., Journal of Nanobiotechnology, 2006). Prior to this

disclosure, it was unknown what effect the introduction of both the deletion and the insertions would have on CPV VP2 expression and subsequent capsid formation.

[0179] The truncated VP2 gene (deletion of 9 amino acids in the N-terminal replaced by additional MLK) and optimized for mammals (Geneart) was further cloned into plasmid pVL1393 using the Bam HI and Xba I sites of both the vector and insert.

[0180] Baculovirus vector generation and protein expression. Baculovirus vector: AcNPV modified by a lethal deletion which is only rescued through homologous recombination (BaculoGold DNA, Pharmingen).

[0181] Generation of recombinant baculovirus BacMEB073. Plasmid pMEB073 was used to generate a recombinant baculovirus, encoding truncated CPV capsid gene of strain Souriou serotype 2c under control of polyhedrin promoter, by homologous recombination. *Spodoptera frugiperda* (Sf) 9 insect cells were co-transfected with plasmid pMEB073 and Bsu36I triple-cut linearized AcNPV DNA, according to manufacturer's protocol (Baculogold, Pharmingen). Recombinant baculovirus from co-transfection supernatant were plaque purified twice. Five clones were amplified (passage 1) at 28°C at a 25 cm^2 monolayer flask scale. Infected cells and supernatants were analysed for CPV capsid expression by Dot Blot using monoclonals specific of CPV capsid antigen (CPV103B10A). Clone 1 showed a correct Dot Blot profile. This clone was further amplified (passage 2) at 28°C at a 50mL scale in Erlenmeyer (suspension) at 105 rpm. A third passage (passage 3) at a 200mL scale was performed to obtain virus stock used for protein expression. This virus stock was then titrated by plaque assay. Virus stock was obtained using SF900II media, supplemented with 2% of FCS.

[0182] After titration recombinant baculovirus stock (Passage 3) was used for protein production in serum free medium.

Expression analysis

Table 3. Expected recombinants

Plasmid	Size (AA)	PM (kDa)	signal peptide	N-Glycosylation site	Disulfide bridge	Sub-cellular location
pMEB073	578	64.1	no	11, 19, 40, 50, 58, 66, 72, 79, 80, 511	no	secreted

[0183] Insect cells (Sf9) were infected with BacMEB073 at MOI = 1 pfu/ml. Insect cells were grown at 105 rpm in Sf900II medium without FCS during 4 days at 28°C. Protein production

was analyzed by submitting whole Sf9 lysates and culture supernatant to SDS-PAGE (4-20%, Invitrogen) followed by Dot Blot with monoclonal antibody (CPV103B10A).

[0184] The solubility of the expressed proteins was studied by lysing the cellular pellets in lysis buffer (50 mM Tris-Hcl pH8, 500 mM NaCl + anti protease), sonication 3X (15" at 20% of potency, 30" wait, 15" at 20% potency, 5' break on ice). Soluble proteins were separated from the insoluble material by centrifugation (30' min at 11 000 rcf at 4°C).

[0185] Results and conclusion. A band at expected size of 64 kDa is expressed in the cell pellet of infected cells lysed and clarified as observed by coomassie staining. The protein accumulated in cells, but was detectable in the soluble fraction after lysis. The identity of VP2 protein was confirmed by Dot Blot using a specific CPV capsid mAb (CPV103B10A).

[0186] EM analysis confirmed auto-assembly of the capsid protein into VLPs with a diameter of 25-30 nm, as well as a correct morphology of parvovirus - like virions at a concentration of 10^{12} VLPs per ml (FIG. 4). VLP production was optimal at MOI=0.1 with harvest 5 days post infection, although other conditions may also yield high levels of VLP.

Example 3 Vaccination of canines with Baculovirus expressed CPV capsid protein

[0187] The primary objective of the study was to assess and compare the safety and immunogenicity of 2 Virus Like Particles (VLPs) of the CPV2c strain Souriou in puppies (i.e. BacMEB072 and BacMEB073, described in Examples 1 and 2). A secondary objective was to assess the adjuvant effects of aluminium hydroxide/saponin or iscomatrix on the immunogenicity of the VLPs produced by BacMEB072 and BacMEB073. Eight week-old puppies were vaccinated and surveyed as indicated in Table 4.

Table 4. Experimental design for truncated CPV VP2 VLP v. Full length CPV VP2 MLV study

Group	Antigen: VLP CPV2	Adjuvant	Vaccination	Clinical monitoring	Sera	Whole blood (sodium heparin)
A (n=6)	BacME073 (truncated)	None	D0 & D28 by SC with 1 ml containing 25 µg of active ingredient	D0, D0+4-6h, D1, D2 D28, D28+4-6h, D29, D30	D-7, D0*, D7, D28, D35, D42, D70	D35, D42
B (n=6)	BacME073 (truncated)	Gel $Al(OH)_3$ (1.7 mg) + Saponin (12 haemolytic units)				
C (n=6)	BacME072 (non-truncated)	None				

D (n=6)	BacME072 (non-truncated)	Gel $Al(OH)_3$ (1.7 mg) + Saponin (12 haemolytic units)				
E (n=6)	BacME072 (non-truncated)	Iscomatrix (75 µg)				
F (n=5)	Control		Control			

* before vaccination

[0188] In terms of safety, $Al(OH)_3$/Saponin induced no general reactions nor any other signs except local heat and swellings. Mild swelling was observed for 3 to 4 days after each vaccination in most of the dogs. Iscomatrix appears to be a very safe adjuvant. In terms of immunogenicity, vaccination of puppies with VLP CPV2 was able to induce both humoral and cellular immune response with no major differences between truncated or full length VP2 associated in VLPs. Notably, the persistence of humoral immune response was increased when VLPs were adjuvanted either with $Al(OH)_3$/Saponin or with Iscomatrix with no significant difference between the two adjuvants investigated. Moreover, Iscomatrix adjuvant increased the magnitude of IFN gamma response not only compared to the non- adjuvanted group but also to $Al(OH)_3$ and Saponin group.

Example 4 Vaccination of canines with Baculovirus expressed CPV VLPs or MLV CPV (strains Souriou or Bari)

[0189] The objective of the study was to compare the immune response in puppies vaccinated with CPV VLP, Souriou CPV MLV or Bari CPV MLV. The first experiment compared 1.52 log10 TCID50/mL (IFI) Souriou; 1.0 log10 TCID50/mL (HA) Bari; and pMEB072 VLP (results in FIG. 8). The second experiment compared 2.21 log10 TCID50/mL (IFI) Souriou; 2.0 log10 TCID50/mL (HA) Bari; and pMEB073-produced VLP in $Al(OH)_3$ + saponin adjuvant (results in FIG. 9). Finally, the third experiment compared 3.81 log10 TCID50/mL (IFI) Souriou; 3.0 log10 TCID50/mL (HA) Bari; and pMEB072-produced VLP in $Al(OH)_3$ + saponin adjuvant (results in FIG. 10). Taken together, these results showed that CPV VLP, made according to the instant disclosure, provided a comparable immune response when compared to exemplar CPV MLV. Importantly, the VLPs were able to induce a more rapid immune response when compared to both the low and intermediate doses of either MLV strain.

[0190] Example 5 Vaccination of canines with CPV MLV or Baculovirus-expressed CPV capsid protein + MLV CPV

[0191] The objective of the study was to evaluate the immunogenicity of different vaccine candidates administered at different doses and subcutaneously in puppies with maternal antibodies. Prior to this study, it was not known whether CPV VLP could overcome maternal antibodies to induce protective immunity in puppies.

Table 5. Experimental design for CPV VLP v. CPV MLV study

Group		Vaccine administered SC on Day 0	Blood Sample (6 mL /puppy)	Analysis
A	CPV MLV (n = 9)	CPV2 MLV 5.5log10 (1ml)	D0*, D7, D14, D21, D28, D34, D42, D56	Anti-CPV Antibody Determination (Hemagglutination Inhibition and/or ELISA)
B	CPV VLP + CPV MLV (n= 10)	CPV VLP *Target dose: 500 µg (1ml)* + CPV2 MLV 5.5log10 (1ml)		

[0192] As indicated in FIG. 11, FIG. 12 and Table 6, CPV antibody titers were significantly higher in the MLV + VLP group. These data indicate that the addition of CPV VLP to the vaccine formulation was sufficient to overcome the maternal antibodies, a surprising and unexpected result. The inventors envision that VLP are capturing a significant proportion of circulating CPV MDA which in turn allows the VLP and CPV MLV to actively immunize puppies.

[0193] Table 6. Anti-CPV antibody titers (IHA) according to days post vaccination

Group	**ID**	**0**	**7**	**14**	**21**
MLV	2252826	10	<5	2560	320
MLV	2253001	10	<5	1280	<5
MLV	2284928	80	<5	<5	<5
MLV	2284973	80	20	<5	20
MLV	2284975	80	20	<5	10
MLV	2285160	<5	<5	<5	5
MLV	2285360	160	40	<5	20
MLV	2285367	40	<5	<5	20
MLV	2285387	10	5	<5	<5
MLV+VLP	2252827	80	640	1280	320
MLV+VLP	2252828	5	160	5120	2560
MLV+VLP	2284818	10	640	2560	2560
MLV+VLP	2284843	10	640	2560	1280
MLV+VLP	2284861	20	1280	1280	1280
MLV+VLP	2284935	40	640	1280	320
MLV+VLP	2284941	80	640	1280	640
MLV+VLP	2284943	20	320	1280	1280

MLV+VLP	2284978	40	1280	1280	1280
MLV+VLP	2285000	80	320	640	640

MLV: Modified Live Vaccine (PRIMODOG® 5.5log10/ml)
VLP: Virus Like Particle, 500 µg

Example 6 Vaccination of canines with Baculovirus-expressed CPV capsid protein, MLV CPV or Adenovirus-vectored CDV

[0194] The objective of the study was to evaluate the immunogenicity of several doses of different vaccine candidates administered via different routes. The different candidates were CPV VLP, and recombinant adenoviruses expressing either CPV or CDV (canine distemper) genes.

Table 7. Experimental design for CPV VLP v. Adeno CPV v. Adeno CDV study

Group		Vaccine administered at D0 and D28** Dose and Route	Samples Taken	Analyses	
A	VLP+_1 (n=6)	VLP CPV *High dose* (500 µl stock solution/dose) SC (1 mL)	Blood vials: D0, D7, D14, D21, D28, D35, D42, D56 and D63 Heparin blood vials: D7, D31, D35, D56	Determination of anti-CDV antibodies (ELISA and/or Hemagglutination Inhibition)	Cellular and/or B Memory Cell Immune Response
B	VLP+_2 (n=6)				
C	VLP-** (n=6)	VLP CPV *Low dose* (50 µl stock solution / dose) SC (1 mL)			
D	VLP_Oral (n=6)	VLP CPV 2 ml undiluted stock solution Oral			
E	Ad5_CPV+ (n=6)	Adeno CPV vAD3032 *high dose* target dose (8.64 log 10 TCID50/mL*) SC (1 mL)			
F	Ad5_CPV (n=6)	Adeno CPV vAD3032 *low dose* (target dose 7.64 log 10 TCID50/mL*) SC (1 mL)			

G	Ad5_CDV- (n=6)	Adeno CDV vAD3031 *low dose* (target dose 7.34 log 10 TCID50/mL*) SC (1 mL)		Determination of anti-CDV antibodies (Seroneutralization)	
H	Ad5_CDV+ (n=6)	Adeno CDV vAD3031 *high dose* (target dose 8.34 log 10 TCID50/mL*) SC (1 ml)			

[0195] As indicated in FIG. 13, Groups A and E induced in puppies protective levels of CPV antibody titers.

Example 7 Vaccination of canines with Baculovirus-expressed CPV capsid protein (VLP), VLP + RECOMBITEK® C4, RECOMBITEK® C4 alone or NOBIVAC® 3

[0196] The objective of the study was to assess the antibody response following the administration of various experimental multivalent vaccine formulations containing conventional CPV-2 MLV or baculovirus-expressed, CPV-2c recombinant Virus Like Particle Vaccine (VLP) and one competitor/commercial vaccine in dogs with CPV MDAs.

[0197] Forty 6-7 week old maternal derived antibodies (MDAs) positive beagle dogs from bitches previously immunized for CPV during pregnancy, were randomly assigned to four treatment groups (n=1 0 dogs) using litter and antibody titer. Titrations from blood samples collected on Day -27 were used for the randomization. All dogs were vaccinated twice, 21 days apart with the assigned vaccine according to Table 8 below. Puppies have CPV maternally derived Ab (MDA) at Do.

Table 8. Experimental design for CPV VLP v. RECOMBITEK® C4 and NOBIVAC® study

Groups	**Vaccination at Day 0 and Day 21**	**Titers**	**No. Dogs**
1	CPV VLP Test Vaccine #4 (1 ml) *VLPs CPV-2c	273.5 µg total protein 7.1 Log HA Titer	10

2	CPV VLP #4 (0.5 ml) *VLPs CPV-2c + RECOMBITEK® C4 #1 (CDV- CAV-CPi, CPV2)*** (1 ml)	273.5 µg total protein 7.1 Log HA Titer CPV: 6.9 TCID50/ml CDV: 7.1 TCID50/ml CPi: 5.8 TCID50/ml CAV2: 6.0 TCID50/ml	10
3	RECOMBITEK® C4 #1 (CDV- CAV-CPi, CPV2)*** (1 ml)	CPV: 6.9 TCID50/ml CDV: 7.1 TCID50/ml CPi: 5.8 TCID50/ml CAV2: 6.0 TCID50/ml	10
4	NOBIVAC® 3 (CDV- CAV2-CPV2) (1 ml)	Unknown	10

*Virus Like Particles of canine Parvovirus VP2: VLPs CPV-2c

**Administered on the same side as the concurrent vaccine approximately 3 cm away

***CDV-CAV-CPi-CPV2 vaccine is referred as C4

HA: Hemagglutination in 0.5 ml

[0198] Blood was collected from all dogs on Days 0, 7, 15, 21, 28, 35 and 42 and the sera were tested for CPV antibodies by the HAI and Serum Neutralization Antibodies (SNA) assays.

[0199] The CPV HAI titers were reported as the inverse of the highest dilution preventing hemagglutination and a value <20 was considered negative.

[0200] Except for 2 dogs in group 3 (C4) all dogs in each group tested positive to CPV by HAI on Day 0, prior to vaccination. Seroconversion following vaccination was defined as an increase in titer by 4 fold or more from Day 0. Following the first vaccination, 6 out 10 dogs vaccinated with the VLP-CPV2c (Group 1) and 6 out 10 dogs vaccinated with VLP-CPV2c- C4 (Group 2) seroconverted by Day 7. There were no responders in groups 3 and 4 (i.e. groups not containing VLPs) on Day 7. By Day 21, 5 out 10 dogs from Group 2 (VLP-CPV2c- C4), 4 out 10 from Group 1 (VLP-CPV2c), 3 out 10 from Group 4 (NOBIVAC3®) and 2 out 10 from Group 3 (C4) seroconverted (FIG. 15).

[0201] Following the second vaccination, by Day 35 (2 weeks post-vax) seroconversion was observed in all dogs from Groups 2 (VLP-CPV2c- C4) and 4 (NOBIVAC3®) followed by 9 in Group 3 (C4) and 8 in Group 1 (VLP-CPV2c). The VLP + C4 (Group 2) treatment induced the highest geometric mean antibody titer throughout the study. See FIG. 17. Seven days after V2,

on Day 28, the GMT of this group was -7.5 times higher than VLP alone (GMT= 520), -9 times higher than C4 alone (GMT =422) and -28 times higher than the NOBIVAC3® group (GMT=139).

Table 9. IHA Titers by ID and Day for CPV VLP v. RECOMBITEK® C4 and NOBIVAC® study

			Day						
			0	7	15	21	28	35	42
Group	Vaccine	Dog ID							
1	VLP CPV-2c	LCR-5	80	40	<20	<20	40	40	40
		LGR-5	40	40	<20	<20	640	1280	1280
		LRR-5	20	160	160	160	10240	1280	1280
		LVQ-5	20	80	80	80	2560	640	640
		QQR-5	20	320	40	20	160	160	160
		RCR-5	40	320	80	20	640	640	640
		RDR-5	20	160	320	640	2560	1280	640
		RGQ-5	20	320	320	320	1280	640	320
		RLQ-5	80	80	40	<20	80	160	320
		RRR-5	80	40	20	<20	80	320	160
2	VLP CPV-2c+ rDAPPI	LDR-5	20	160	160	40	5120	1280	640
		LHR-5	40	40	<20	<20	1280	640	640
		LSQ-5	20	1280	1280	640	20480	5120	2560
		LWQ-5	40	160	5120	2560	20480	5120	5120
		PKR-5	40	20	<20	<20	1280	1280	1280
		PLQ-5	40	80	1280	640	20480	5120	5120
		QRR-5	20	160	1280	1280	5120	2560	2560
		RHQ-5	20	320	640	1280	5120	2560	1280
		ROQ-5	40	40	20	<20	320	640	640
		RSQ-5	40	160	40	40	1280	640	320
3	rDAPPI	LPR-5	20	<20	160	160	1280	640	640
		LQR-5	20	<20	160	160	640	640	320
		LTQ-5	20	<20	<20	<20	640	320	640
		PIR-5	20	<20	<20	<20	160	320	640
		POQ-5	<20	<20	<20	<20	1280	640	1280
		QSR-5	40	20	20	<20	160	320	160
		RER-5	<20	<20	<20	<20	640	320	640
		RIQ-5	20	<20	<20	<20	1280	320	640
		RPQ-5	80	40	20	20	<20	<20	<20
		RTQ-5	20	20	<20	<20	640	320	320
4	Nobivac	LER-5	40	20	<20	<20	<20	640	640

			Day						
			0	7	15	21	28	35	42
Group	Vaccine	Dog ID							
		LFR-5	20	<20	<20	<20	640	1280	1280
		LUQ-5	40	20	<20	<20	40	1280	1280
		PJR-5	20	<20	<20	<20	<20	640	640
		QTR-5	40	20	<20	<20	160	2560	1280
		RFR-5	20	<20	1280	640	1280	1280	1280
		RJQ-5	20	<20	80	640	1280	2560	1280
		RKR-5	40	20	20	<20	40	1280	1280
		RQR-5	40	20	<20	<20	160	320	320
		RUQ-5	40	20	20	640	160	320	640

Table 10. Summary Statistics for CPV VLP v. RECOMBITEK® C4 and NOBIVAC® study

Day	Group	Vaccine	N	Geometric Mean	Arithmetic Mean	Median	Min	Max
0	1	VLP CPV-2c	10	34.82	42.00	30	20.0	80.0
	2	VLP CPV-2c+ rDAPPI	10	30.31	32.00	40	20.0	40.0
	3	rDAPPI	10	24.62	28.00	20	20.0	80.0
	4	Nobivac	10	30.31	32.00	40	20.0	40.0
7	1	VLP CPV-2c	10	113.14	156.00	120	40.0	320.0
	2	VLP CPV-2c+ rDAPPI	10	121.26	242.00	160	20.0	1280.0
	3	rDAPPI	10	21.44	22.00	20	20.0	40.0
	4	Nobivac	10	20.00	20.00	20	20.0	20.0
15	1	VLP CPV-2c	10	64.98	110.00	60	20.0	320.0
	2	VLP CPV-2c+ rDAPPI	10	226.27	986.00	400	20.0	5120.0
	3	rDAPPI	10	30.31	48.00	20	20.0	160.0
	4	Nobivac	10	34.82	152.00	20	20.0	1280.0
21	1	VLP CPV-2c	10	52.78	132.00	20	20.0	640.0
	2	VLP CPV-2c+ rDAPPI	10	171.48	654.00	340	20.0	2560.0
	3	rDAPPI	10	30.31	48.00	20	20.0	160.0
	4	Nobivac	10	56.57	206.00	20	20.0	640.0
28	1	VLP CPV-2c	10	519.84	1828.00	640	40.0	10240.0
	2	VLP CPV-2c+ rDAPPI	10	3880.23	8096.00	5120	320.0	20480.0
	3	rDAPPI	10	422.24	674.00	640	20.0	1280.0
	4	Nobivac	10	139.29	380.00	160	20.0	1280.0
35	1	VLP CPV-2c	10	422.24	644.00	640	40.0	1280.0
	2	VLP CPV-2c+ rDAPPI	10	1810.19	2496.00	1920	640.0	5120.0
	3	rDAPPI	10	298.57	386.00	320	20.0	640.0

Day	Group	Vaccine	N	Geometric Mean	Arithmetic Mean	Median	Min	Max
	4	Nobivac	10	970.06	1216.00	1280	320.0	2560.0
42	1	VLP CPV-2c	10	367.58	548.00	480	40.0	1280.0
	2	VLP CPV-2c+ rDAPPI	10	1371.87	2016.00	1280	320.0	5120.0
	3	rDAPPI	10	367.58	530.00	640	20.0	1280.0
	4	Nobivac	10	905.10	992.00	1280	320.0	1280.0

* The '<' signs were removed from the values in order to calculate the summary statistics.

Example 8 Vaccination of canines with Baculovirus-expressed CPV capsid protein (VLP), VLP + RECOMBITEK® C4, RECOMBITEK® C4 alone or NOBIVAC® 3

[0202] The objective of this study was to assess the CPV antibody response following the administration of experimental Virus Like Particles made of the VP2 capsid protein of canine Parvovirus type 2c (VLPs CPV-2c) at different titers in combination with a CPV-2 MLV multivalent vaccine formulation and one commercial vaccine in dogs with CPV MDAs.

[0203] Fifty 6-7 week old maternal derived antibodies (MDAs) positive beagle dogs from bitches previously immunized for CPV during pregnancy, were randomly assigned to five treatment groups (n=10 dogs per group) using litter and antibody titer. Titrations from blood samples collected on Day -15 were used for the randomization.

[0204] Vaccines were prepared by rehydrating a lyophilized component with a diluent component. The Lyophilized serial used for the Test vaccines #1, #2, #3 and #5 was the same experimental 4-way (C4) vaccine. The titers for each component were as follow: CPV:6.1 Log TCID50/ml (~0.2 ml of 1X culture), CDV: 7.3 Log TCID50/ml, CPi: 5.5 Log TCID50/ml and CAV2:6.0 Log TCID50/ml. All dogs were vaccinated twice, 21 days apart with the assigned vaccine according to Table 11 below.

Table 11. Experimental design for CPV VLP v. RECOMBITEK® C4 and NOBIVAC® study

GROUP (n=10)	Vaccine Lyophilized component	Vaccine Diluent component
1 C4 + High dose VLP-CPV2c	CDV-CAV2-CPi-CPV	VLPs CPV-2c; lot #: 14Dec15 Undiluted 7.0 Log aHA / ml ~10 ml of 1X culture
2 C4 + Mid	CDV-CAV2-CPi-CPV	VLPs CPV-2c; lot #: 14Dec15 Diluted 1:5 in water

dose VLP-CPV2c		6.3 Log aHA / ml ~2 ml of 1X culture
3 C4 + Low dose VLP-CPV2c	CDV-CAV2-CPi-CPV	VLPs CPV-2c; lot #: 14Dec15 Diluted 1:25 in water 5.7 Log aHA / ml ~0.4 ml of 1X culture
4 Nobivac® 3 DAPv	Nobivac® Canine 3 (CDV- CAV2-CPV2) (1 ml)	Unknown
5 C4 No VLP-CPV2c	CDV-CAV2-CPi-CPV	Water

[0205] Blood was collected from all dogs on Days 0, 7, 15, 21, 28, 34 and 42 and the sera were tested for CPV antibodies by the HAI assay.

[0206] The CPV HAI titers were reported as the inverse of the highest dilution preventing hemagglutination and a value <20 was considered negative. All dogs in each group tested positive to CPV by HAI on Day 0, prior to vaccination (GMT average titers for all groups between 42.87 and 80). Seroconversion following vaccination was defined as an increase in titer by 4 fold or more from Day 0. Dogs seroconverting were categorized as responders (FIG. 18). Seven days after the first vaccination, 5 out 10 dogs vaccinated with the high dose VLP-CPV2c-C4 (Group 1) and 1 out 10 dogs vaccinated with mid dose VLP-CPV2c-C4 (Group 2) seroconverted . There were no responders in groups 3, 4 and 5 (i.e. groups containing low or no VLPs) on Day 7. Twenty-one days after the first vaccination, all dogs from Group 1 (high dose VLP-CPV2c- C4), 3 out 10 from Group 2 (mid dose VLP-CPV2c- C4), 1 out 10 from Group 3 (low dose VLP-CPV2c- C4). There were no responders in groups 4 and 5 (i.e. groups not containing VLPs) (FIG. 18).

[0207] On Day 34, 13 days following the second vaccination, seroconversion was observed in all dogs from Groups 1 (high dose VLP-CPV2c-C4) and 4 (NOBIVAC3®) followed by 9 in Group 2 (mid dose VLP-CPV2c- C4) 6 in Group 3 (low dose VLP-CPV2c-C4) and 1 in Group 5 (C4 no VLP).

[0208] As shown in FIG. 19, the high dose VLP + C4 (Group 1) treatment induced the highest geometric mean antibody titer throughout the study. Thirteen days after V2, on Day 34, the GMT of this group was 4457.22, followed by the mid dose VLP-CPV2c-C4 and the NOBIVAC3®

groups; (GMT=1470.33), the low dose VLP-CPV2c-C4 (GMT =298.57) and C4 alone (GMT =45.95).

Table 12. HI Results by Group, ID and Day for second CPV VLP v. RECOMBITEK® C4 and NOBIVAC® study

			Day						
			0	7	15	21	28	34	42
Group	*Vaccine	ID							
1	Test Vaccine #1 (rDAPP; C4) + VLPs CPV-2c 7.1 Log HA	PFE6	40	320	640	1280	5120	5120	2560
		PRD6	40	5120	5120	2560	5120	5120	2560
		QFC6	40	5120	5120	5120	10240	10240	5120
		QOE6	20	160	2560	2560	10240	5120	5120
		RIE6	80	80	40	20	1280	2560	2560
		RKD6	80	320	1280	640	10240	5120	2560
		SPF6	160	80	2560	1280	10240	10240	5120
		TAF6	80	160	1280	640	10240	5120	5120
		VAF6	80	160	80	80	640	1280	1280
		VCE6	40	80	80	40	5120	2560	2560
		GMT	*56.57*	*298.57*	*735.17*	*519.84*	*5120.00*	*4457.22*	*3151.73*
2	Test Vaccine #2 (rDAPP; C4) + VLPs CPV-2c 6.4 Log HA	PWF6	40	160	320	160	2560	2560	1280
		QBF6	160	160	80	40	640	640	320
		QLE6	40	80	1280	2560	10240	10240	5120
		RJD6	80	80	320	160	2560	1280	1280
		RWE6	80	80	20	<20	80	2560	1280
		RXE6	40	80	20	20	320	640	640
		STE6	80	40	20	20	40	640	320
		SUF6	40	40	40	20	160	5120	2560
		TBF6	80	40	40	40	320	2560	1280
		VDE6	80	40	40	20	40	160	160
		GMT	*64.98*	*69.64*	*74.64*	*56.57*	*393.97*	*1470.33*	*905.10*
3	Test Vaccine #3 (rDAPP; C4) + VLPs CPV-2c 5.7 Log HA	QDE6	80	40	20	20	40	80	80
		QED6	40	40	320	320	2560	2560	1280
		QKE6	40	20	<20	<20	40	160	160
		RGF6	40	80	40	20	40	1280	640
		RPD6	40	40	20	20	40	1280	640
		RTF6	40	40	20	<20	80	1280	1280
		SCE6	20	20	<20	<20	1280	1280	1280
		SQF6	80	40	40	20	40	160	160

			Day						
			0	7	15	21	28	34	42
Group	*Vaccine	ID							
		UOE6	40	20	20	<20	40	20	<20
		UXF6	40	40	20	20	20	<20	<20
		GMT	*42.87*	*34.82*	*30.31*	*26.39*	*85.74*	*298.57*	*242.51*
4	Nobivac® Canine 3-DAPv	PCE6	20	<20	<20	<20	40	640	640
		QCF6	80	40	20	<20	<20	2560	640
		RFF6	160	40	20	20	20	1280	640
		RLD6	160	160	20	<20	<20	2560	1280
		ROD6	160	40	20	<20	<20	1280	1280
		SDE6	40	40	20	<20	40	1280	1280
		SWE6	40	20	<20	<20	<20	640	320
		SXE6	40	20	20	<20	<20	1280	1280
		TCE6	160	40	<20	20	<20	2560	1280
		UYF6	160	160	40	40	<20	2560	1280
		GMT	*80.00*	*42.87*	*21.44*	*21.44*	*22.97*	*1470.33*	*905.10*
5	Test Vaccine #5 (rDAPP; C4)	PBE6	20	<20	<20	<20	80	1280	640
		REF6	80	40	20	<20	<20	<20	<20
		RHE6	160	20	<20	<20	<20	<20	<20
		RUE6	80	80	40	20	<20	<20	<20
		SVF6	160	<20	<20	<20	<20	<20	<20
		TDE6	160	160	40	<20	<20	<20	<20
		ULF6	20	20	<20	<20	<20	320	320
		UPE6	80	20	<20	<20	<20	80	320
		UZF6	160	160	40	20	20	<20	<20
		VBF6	80	20	20	20	<20	<20	<20
		GMT	*80.00*	*37.32*	*24.62*	*20.00*	*22.97*	*45.95*	*49.25*

* For the purpose of Example 8, the below names will be used in the following tables and charts.

* C4 + High dose VLP-CPV2c = Test Vaccine #1
* C4 + Mid dose VLP-CPV2c = Test Vaccine #2
* C4 + Low dose VLP-CPV2c = Test Vaccine #3
* C4 + No VLP-CPV2c = Test Vaccine #5

Table 13. Summary Statistics* by group for second CPV VLP v. RECOMBITEK® C4 and NOBIVAC® study

Day	Group	Vaccine	N	Geometric Mean	Arithmetic Mean	Median	Min	Max
0	1	C4 + High dose VLP-CPV2c	10	56.57	66.00	60	20.0	160.0
	2	C4 + Mid dose VLP-CPV2c	10	64.98	72.00	80	40.0	160.0
	3	C4 + low dose VLP-CPV2c	10	42.87	46.00	40	20.0	80.0

Day	Group	Vaccine	N	Geometric Mean	Arithmetic Mean	Median	Min	Max
	4	Nobivac® Canine 3-DAPv	10	80.00	102.00	120	20.0	160.0
	5	C4 + No VLP-CPV2c	10	80.00	100.00	80	20.0	160.0
7	1	C4 + High dose VLP-CPV2c	10	298.57	1160.00	160	80.0	5120.0
	2	C4 + Mid dose VLP-CPV2c	10	69.64	80.00	80	40.0	160.0
	3	C4 + low dose VLP-CPV2c	10	34.82	38.00	40	20.0	80.0
	4	Nobivac® Canine 3-DAPv	10	42.87	58.00	40	20.0	160.0
	5	C4 + No VLP-CPV2c	10	37.32	56.00	20	20.0	160.0
15	1	C4 + High dose VLP-CPV2c	10	735.17	1876.00	1280	40.0	5120.0
	2	C4 + Mid dose VLP-CPV2c	10	74.64	218.00	40	20.0	1280.0
	3	C4 + low dose VLP-CPV2c	10	30.31	54.00	20	20.0	320.0
	4	Nobivac® Canine 3-DAPv	10	21.44	22.00	20	20.0	40.0
	5	C4 + No VLP-CPV2c	10	24.62	26.00	20	20.0	40.0
21	1	C4 + High dose VLP-CPV2c	10	519.84	1422.00	960	20.0	5120.0
	2	C4 + Mid dose VLP-CPV2c	10	56.57	306.00	30	20.0	2560.0
	3	C4 + low dose VLP-CPV2c	10	26.39	50.00	20	20.0	320.0
	4	Nobivac® Canine 3-DAPv	10	21.44	22.00	20	20.0	40.0
	5	C4 + No VLP-CPV2c	10	20.00	20.00	20	20.0	20.0
28	1	C4 + High dose VLP-CPV2c	10	5120.00	6848.00	7680	640.0	10240.0
	2	C4 + Mid dose VLP-CPV2c	10	393.97	1696.00	320	40.0	10240.0
	3	C4 + low dose VLP-CPV2c	10	85.74	418.00	40	20.0	2560.0
	4	Nobivac® Canine 3-DAPv	10	22.97	24.00	20	20.0	40.0
	5	C4 + No VLP-CPV2c	10	22.97	26.00	20	20.0	80.0
34	1	C4 + High dose VLP-CPV2c	10	4457.22	5248.00	5120	1280.0	10240.0
	2	C4 + Mid dose VLP-CPV2c	10	1470.33	2640.00	1920	160.0	10240.0
	3	C4 + low dose VLP-CPV2c	10	298.57	812.00	720	20.0	2560.0
	4	Nobivac® Canine 3-DAPv	10	1470.33	1664.00	1280	640.0	2560.0
	5	C4 + No VLP-CPV2c	10	45.95	182.00	20	20.0	1280.0
42	1	C4 + High dose VLP-CPV2c	10	3151.73	3456.00	2560	1280.0	5120.0
	2	C4 + Mid dose VLP-CPV2c	10	905.10	1424.00	1280	160.0	5120.0
	3	C4 + low dose VLP-CPV2c	10	242.51	556.00	400	20.0	1280.0
	4	Nobivac® Canine 3-DAPv	10	905.10	992.00	1280	320.0	1280.0
	5	C4 + No VLP-CPV2c	10	49.25	142.00	20	20.0	640.0

Table 14. Number of Responders (Serocoversion) by Group and Day; 1=Yes, 0=No; Serocoversion is defined as a 4 fold or greater increase in titer from baseline.

			Day						
			0	7	15	21	28	34	42
Group	Vaccine	ID							
1	C4 + High dose VLP-CPV2c	PFE6	0	1	1	1	1	1	1
		PRD6	0	1	1	1	1	1	1
		QFC6	0	1	1	1	1	1	1
		QOE6	0	1	1	1	1	1	1
		RIE6	0	0	0	0	1	1	1
		RKD6	0	1	1	1	1	1	1
		SPF6	0	0	1	1	1	1	1
		TAF6	0	0	1	1	1	1	1
		VAF6	0	0	0	0	1	1	1
		VCE6	0	0	0	0	1	1	1
		Total	*0*	*5*	*7*	*7*	*10*	*10*	*10*
2	C4 + Mid dose VLP-CPV2c	ID							
		PWF6	0	1	1	1	1	1	1
		QBF6	0	0	0	0	1	1	1
		QLE6	0	0	1	1	1	1	1
		RJD6	0	0	1	1	1	1	1
		RWE6	0	0	0	0	0	1	1
		RXE6	0	0	0	0	1	1	1
		STE6	0	0	0	0	0	1	1
		SUF6	0	0	0	0	1	1	1
		TBF6	0	0	0	0	1	1	1
		VDE6	0	0	0	0	0	0	0
		Total	*0*	*1*	*3*	*3*	*7*	*9*	*9*
3	C4 + low dose VLP-CPV2c	ID							
		QDE6	0	0	0	0	0	0	0
		QED6	0	0	1	1	1	1	1
		QKE6	0	0	0	0	0	1	1
		RGF6	0	0	0	0	0	1	1
		RPD6	0	0	0	0	0	1	1
		RTF6	0	0	0	0	0	1	1
		SCE6	0	0	0	0	1	1	1
		SQF6	0	0	0	0	0	0	0
		UOE6	0	0	0	0	0	0	0
		UXF6	0	0	0	0	0	0	0
		Total	*0*	*0*	*1*	*1*	*2*	*6*	*6*

			Day						
			0	7	15	21	28	34	42
4	Nobivac® Canine 3-DAPv	ID							
		PCE6	0	0	0	0	0	1	1
		QCF6	0	0	0	0	0	1	1
		RFF6	0	0	0	0	0	1	1
		RLD6	0	0	0	0	0	1	1
		ROD6	0	0	0	0	0	1	1
		SDE6	0	0	0	0	0	1	1
		SWE6	0	0	0	0	0	1	1
		SXE6	0	0	0	0	0	1	1
		TCE6	0	0	0	0	0	1	1
		UYF6	0	0	0	0	0	1	1
		Total	*0*	*0*	*0*	*0*	*0*	*10*	*10*
5	C4 + No VLP-CPV2c	ID							
		PBE6	0	0	0	0	1	1	1
		REF6	0	0	0	0	0	0	0
		RHE6	0	0	0	0	0	0	0
		RUE6	0	0	0	0	0	0	0
		SVF6	0	0	0	0	0	0	0
		TDE6	0	0	0	0	0	0	0
		ULF6	0	0	0	0	0	1	1
		UPE6	0	0	0	0	0	0	1
		UZF6	0	0	0	0	0	0	0
		VBF6	0	0	0	0	0	0	0
		Total	*0*	*0*	*0*	*0*	*1*	*2*	*3*

[0209] Accordingly, CPV VLPs promoted an earlier onset of immunity (OOI) than MLV alone in MDA+ puppies, and CPV VLPs synergize with MLV C4 in MDA+ puppies. Applicant submits that these results were unexpected and extremely favorable. Overcoming maternally-derived antibodies has long challenged vaccine biologists, and these data indicate that the VLP + MLV approach disclosed herein may be applied broadly to the problem of providing MDA+ offspring with protective immunity.

CLAIMS

What we claim is:

1. A combination vaccine comprising a virus-like particle (VLP) component and a modified-live virus (MLV) component, wherein both the VLP and the MLV are directed against the same pathogen or disease, and wherein the combination vaccine overcomes maternally-derived antibodies (MDA).
2. The combination vaccine of claim 1, which provides protective immunity with a single dose.
3. The combination vaccine of claim 1, wherein the pathogen or disease is canine parvovirus (CPV).
4. The combination vaccine of claim 1, wherein the pathogen or disease is foot-and-mouth disease virus (FMDV).
5. The combination vaccine of claim 3, wherein the VLP component of the combination comprises at least at least 10% CPV VLPs (w/w) as a function of total protein content.
6. The combination vaccine of claim 5, wherein the VLP component comprises at least 20% CPV VLPs (w/w).
7. The combination vaccine of claim 3, wherein the CPV VLP is expressed by a baculovirus vector in insect cells.
8. The combination vaccine of claim 3, wherein the CPV VLP comprises at least one CPV capsid protein.
9. The combination vaccine of claim 3, wherein the CPV VLP comprises a CPV polypeptide having the sequence as set forth in SEQ ID NO: 1, 3, 4, 6, 8, 9 or 10; or,
   wherein the CPV VLP comprises a CPV polypeptide having at least 90% identity a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, 8, 9 or 10.
10. The composition or vaccine of claim 1, wherein the CPV VLP comprises a CPV polypeptide encoded by a polynucleotide having the sequence as set forth in SEQ ID NO: 2, 5 or 7; or,

    wherein the CPV VLP comprises a CPV polypeptide encoded by a polynucleotide having at least 90% identity to a sequence as set forth in SEQ ID NO: 2, 5 or 7.

11. The combination vaccine of claim 1, wherein the composition or vaccine is not adjuvanted and optionally comprises a pharmaceutically or veterinarily acceptable carrier, excipient, or vehicle.

12. A plasmid useful for producing CPV VLP, comprising a polynucleotide encoding a CPV antigen having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10, or a polynucleotide sequence having at least 90% identity to a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

13. The plasmid of claim 12, wherein the polynucleotide comprises or consists of the sequence as set forth in SEQ ID NO: 2, 5, 7, 11 or 12.

14. The plasmid of claim 12, wherein the plasmid consists of the sequence as set forth in SEQ ID NO:11 or 12.

15. The plasmid of claim 12, which is stably transformed into an insect cell, which expresses CPV VLPs.

16. A substantially purified CPV empty capsid or CPV VLP expressed in insect cells, wherein the CPV empty capsid or VLP comprises a polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10; or,

wherein the CPV empty capsid or VLP comprises a polypeptide having at least 90% identity to a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10; or,

17. The purified CPV empty capsid or CPV VLP of claim 16, wherein the CPV empty capsid or VLP consists of a polypeptide having a sequence as set forth in SEQ ID NO: 1, 3, 4, 6, or 8-10.

18. A method of eliciting an immune response in an animal against CPV comprising administering to the animal the composition of any one of claims 1- 7, or the CPV empty capsids or VLPs of claim 16.

19. The method of claim 18, wherein the immune response is protective, and wherein the protective immune response protects vaccinates against subsequent exposure to virulent CPV.

20. The method of claim 19, wherein the protective immune response is elicited in the vaccinated animals, regardless of the presence in said animals of high levels of maternally-derived antibodies (MDA) against CPV.

SEQ ID NO	Type	Gene Description
1	Protein	CPV VP2 - GenBank BAD34656.1
2	DNA	pVL1393 - 9632 bp baculovirus transfer vector
3	Protein	CPV VP2 Souriou (serotype 2c)
4	Protein	Non-Truncated CPV VP2 in pMEB072
5	DNA	pMEB072 Codon-optimized nucleic acid encoding CPV VP2 (SEQ ID NO:4)
6	Protein	Truncated CPV VP2 in pMEB073
7	DNA	pMEB073 codon-optimized nucleic acid sequence encoding CPV VP2 (SEQ ID NO:6)
8	Protein	GenBank: AHW47988.1 (a CPV VP2)
9	Protein	GenBank: AHW47989.1 (a CPV VP2)
10	Protein	GenBank: ADA61118.1 (a CPV VP2)
11	DNA	pMEB072
12	DNA	pMEB073

FIG. 1

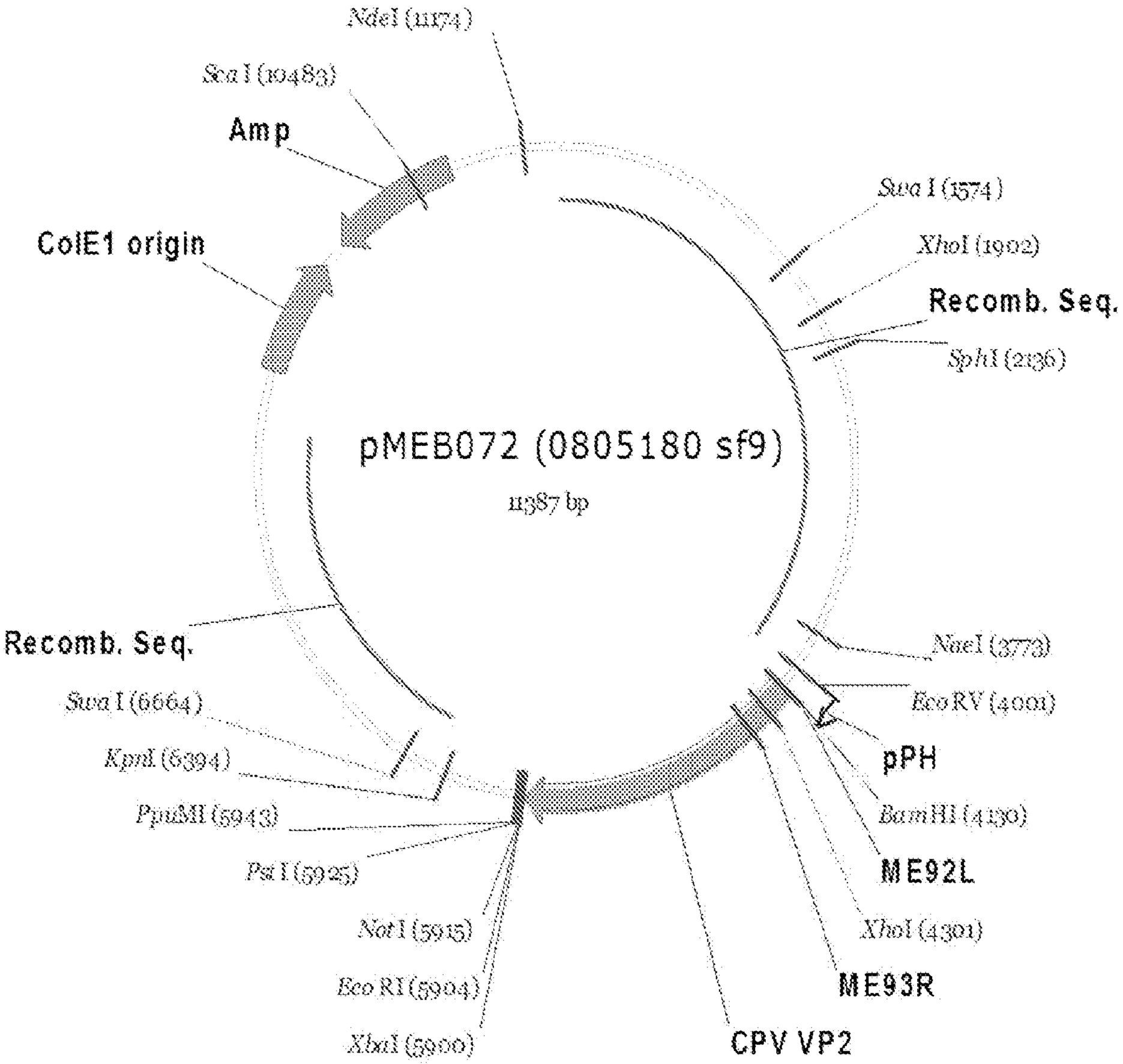
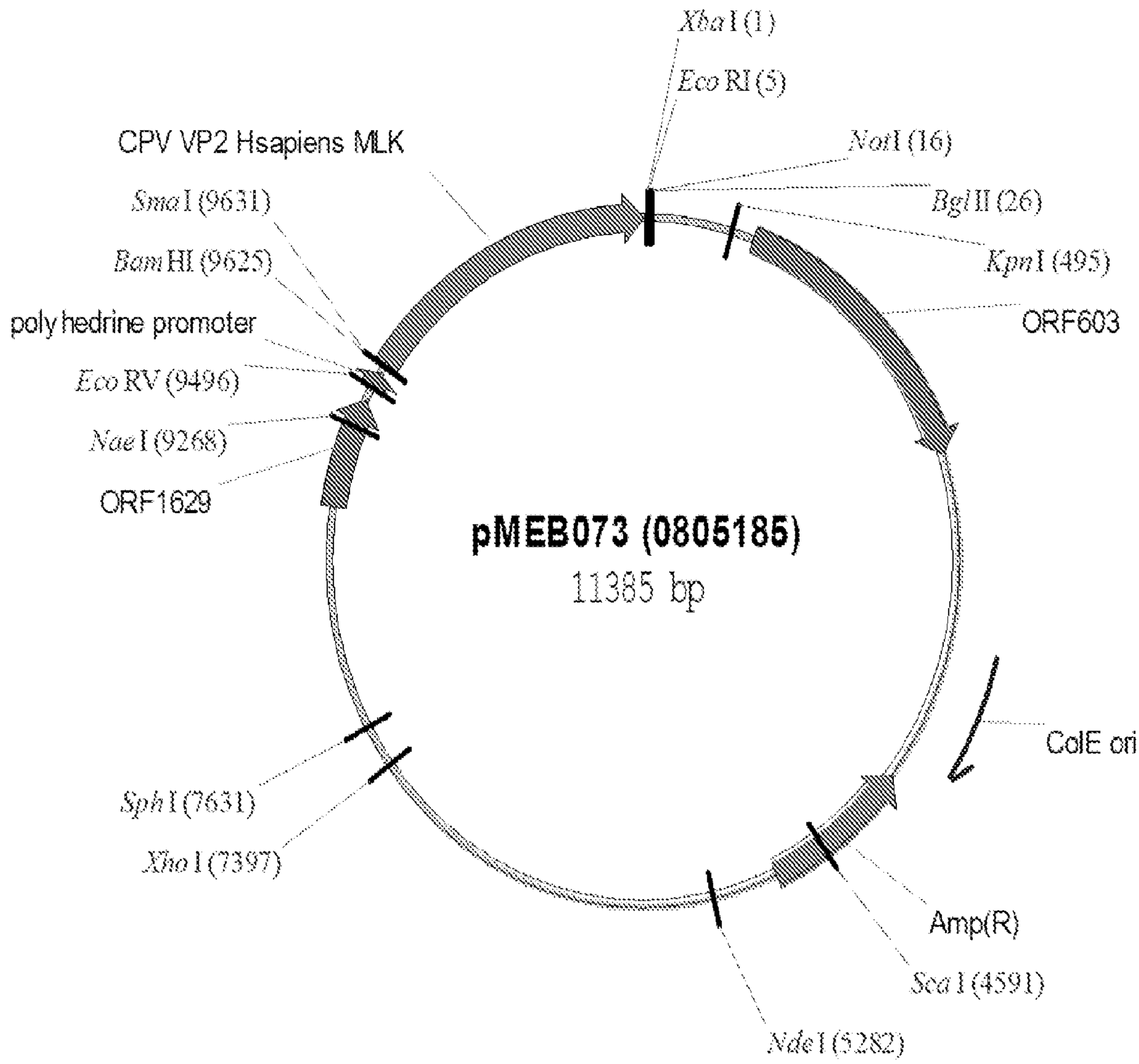

NdeI (1174)
ScaI (10483)
Amp
ColE1 origin
SwaI (1574)
XhoI (1902)
Recomb. Seq.
SphI (2136)
pMEB072 (0805180 sf9)
11387 bp
Recomb. Seq.
NaeI (3773)
SwaI (6664)
EcoRV (4001)
KpnI (6394)
pPH
PpuMI (5943)
BamHI (4130)
PstI (5925)
ME92L
NotI (5915)
XhoI (4301)
EcoRI (5904)
ME93R
XbaI (5900)
CPV VP2
CDS (2 total)
CPV_VP2
Start: 4141 End: 5998
Original Location Description:
4135..5998
Amp
Start: 9932 End: 10720 (Complementary)
Original Location Description:
complement(9932..10720)
Primer (2 total)
Promoter Prokaryotic (1 total)
pPH
Start: 3939 End: 4032
Original Location Description:
3939..4092
Protein Binding Site (2 total)
Recomb. Seq.
Start: 1 End: 3997
Original Location Description:
1..3997
Recomb. Seq.
Start: 6493 End: 8757
Original Location Description:
6493..8757
Replication Origin (1 total)
ColE1 origin
Start: 9111 End: 9784
Original Location Description:
9111..9784

FIG. 2



- CDS (2 total)
  - Amp(R)
    - Start: 4042 End: 4897 (Complementary)
  - CPV_VP2_Hsapiens_MLK
    - Start: 9645 End: 11384
    - Original Location Description:
      - 29..1768
- Promoter Eukaryotic (1 total)
  - polyhedrine promoter
    - Start: 9486 End: 9586
- Misc. Recombination (2 total)
  - ORF603
    - Start: 625 End: 2252
  - ORF1629
    - Start: 8828 End: 9421
- oriT (1 total)
  - ColE ori
    - Start: 3278 End: 3866

FIG. 3

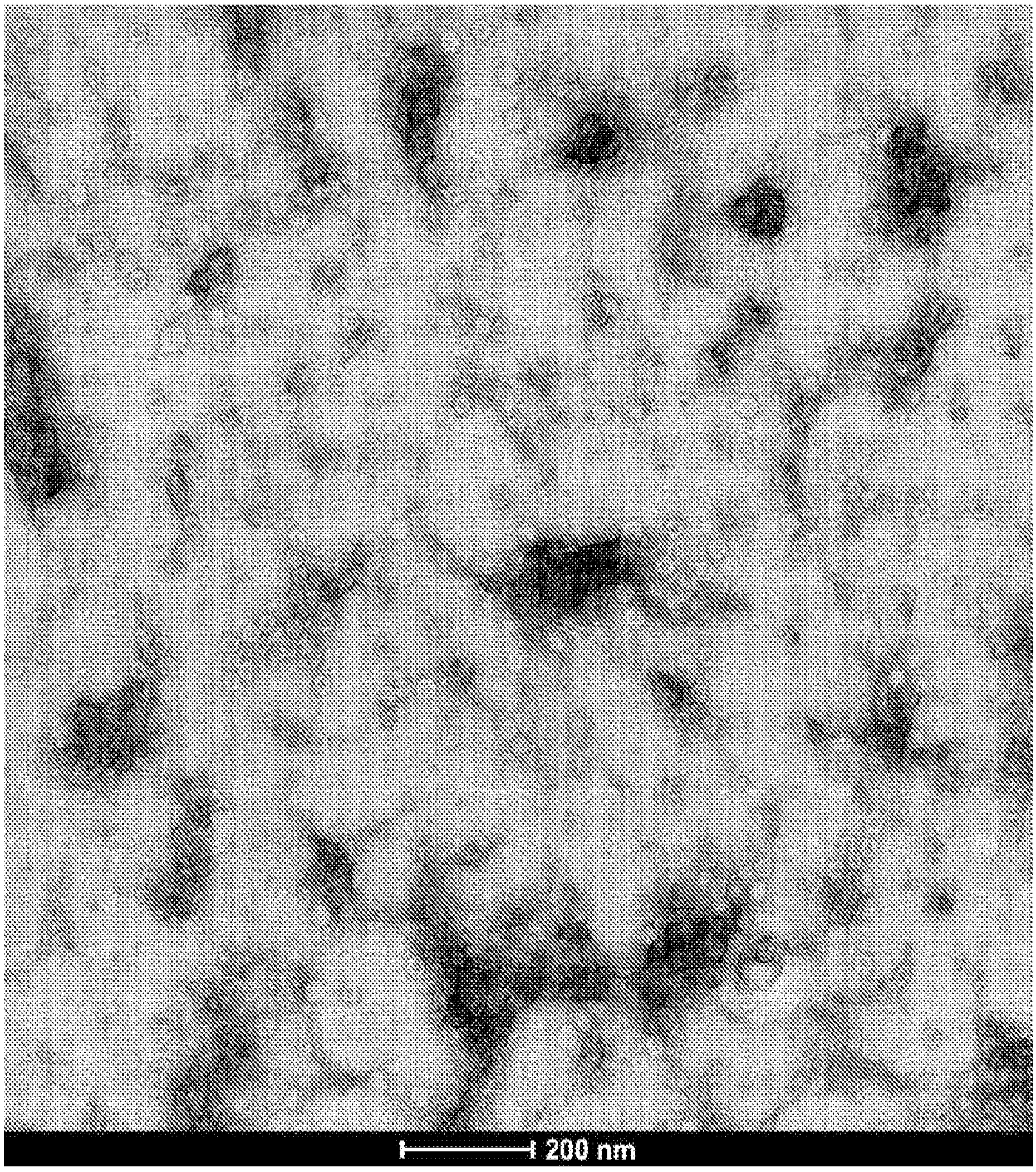
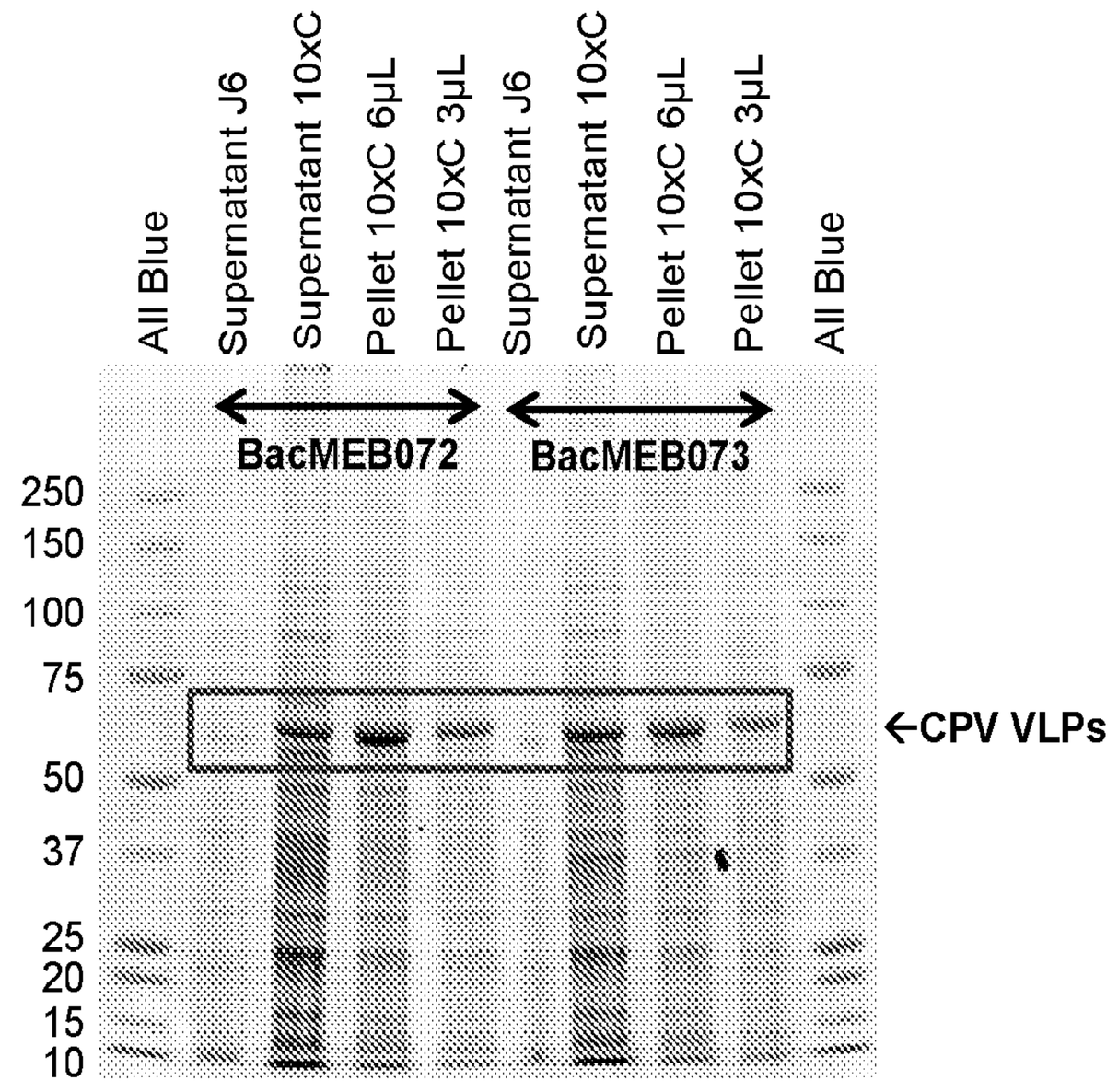
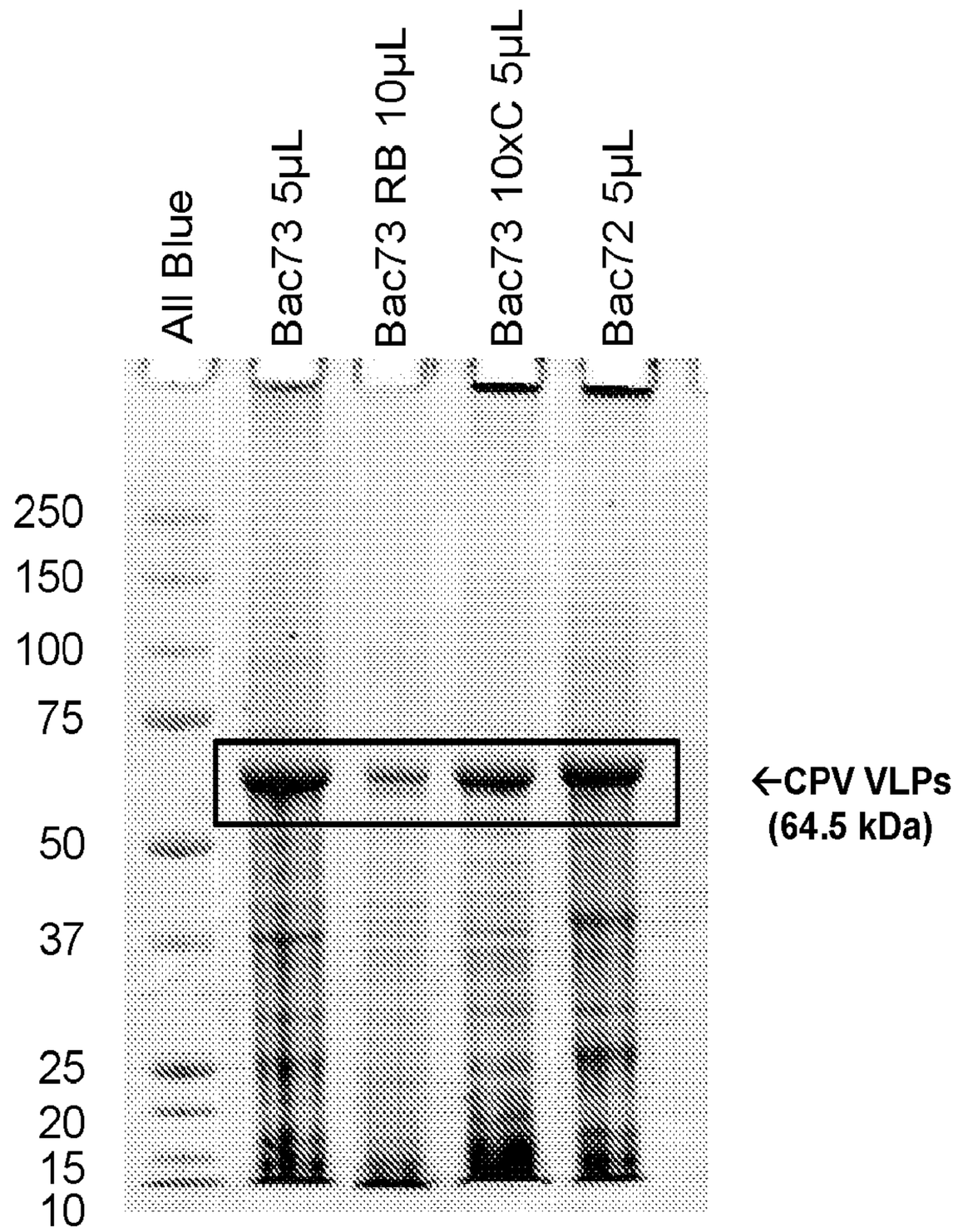


FIG. 4



Batch	Step	VLP Band	Total	% VLPs
BacMEB072	D6 Supernatant	3	28	11
	10x Concentrated Supernatant	20	90	22
	Pellet 6 µL	41	79	52
	Pellet 3 µL	22	52	42
Bac MEB073	D6 Supernatant	2	11	18
	10x Concentrated Supernatant	31	121	26
	Pellet 6 µL	35	64	55
	Pellet 3 µL	17	34	50

FIG. 5



Sample Name	Estimated Purity by SDS	Total Protein µg/ml	[CPV VLPs] µg/ml	ELISA Titer in Log10 DO50/ml
CPV VLP BacMEB073 P4 10x Concentrated	53%	2122	1134	5.48
CPV VLP BacMEB073 P5	54%	503	273	4.99
CPV VLP BacMEB073 P5 10x Concentrated	55%	1986	1096	5.60
CPV VLP BacMEB072 P4 10x Concentrated	43%	2410	1041	5.67

FIG. 6

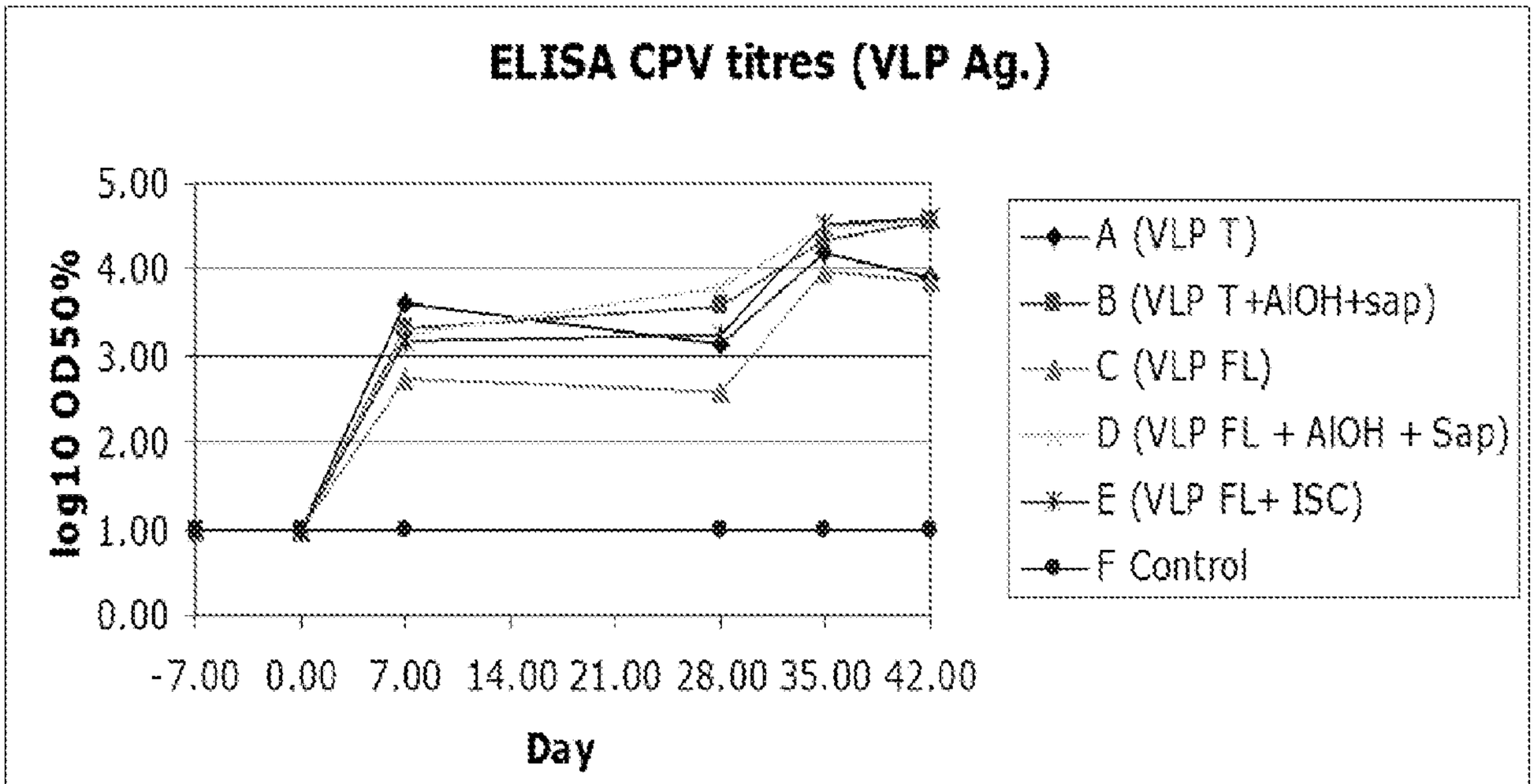

ELISA CPV titres (VLP Ag.)
log10 OD50%
5.00
4.00
3.00
2.00
1.00
0.00
-7.00 0.00 7.00 14.00 21.00 28.00 35.00 42.00
Day
A (VLP T)
B (VLP T+AlOH+sap)
C (VLP FL)
D (VLP FL + AlOH + Sap)
E (VLP FL+ ISC)
F Control

FIG. 7

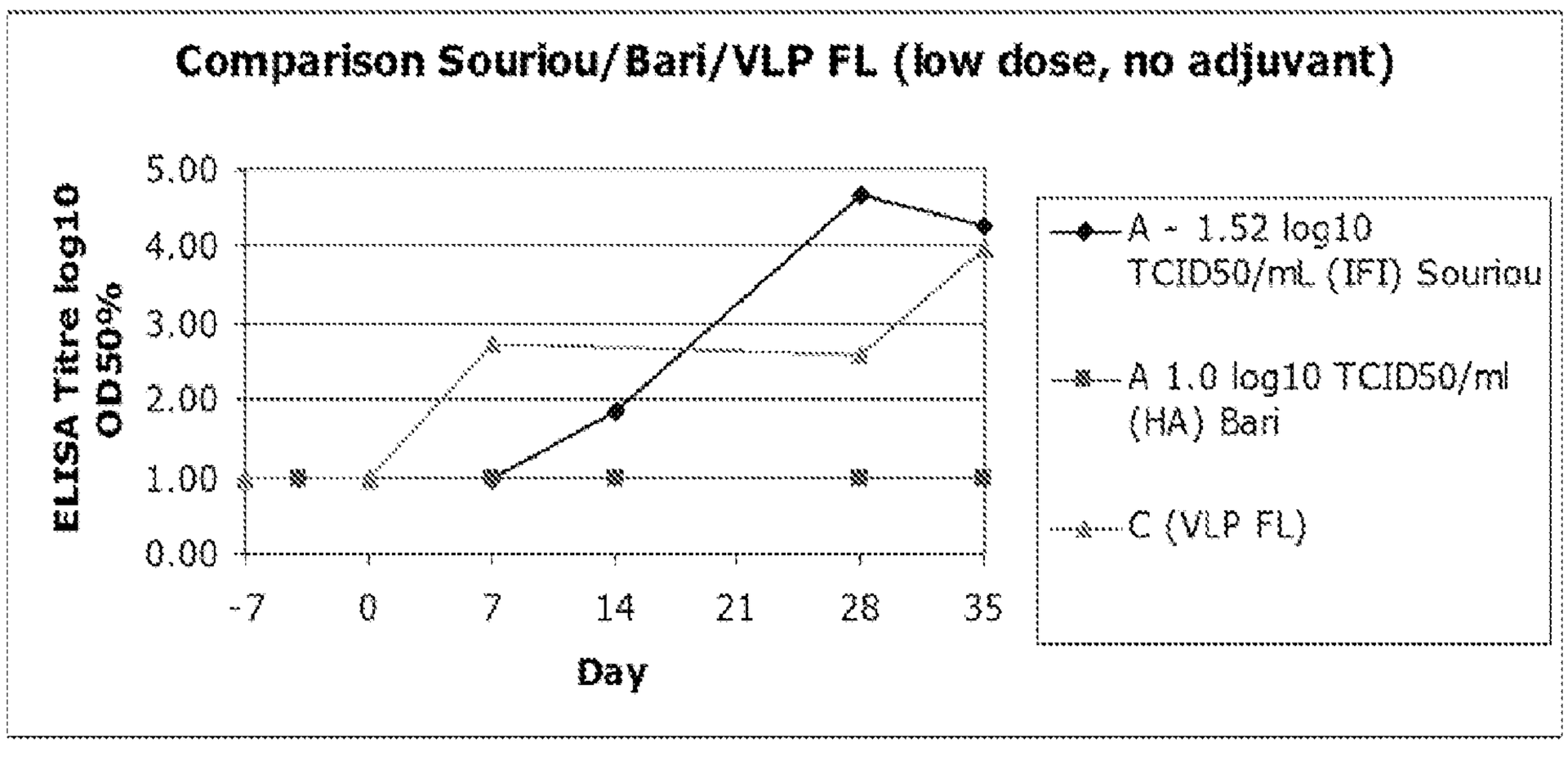

Comparison Souriou/Bari/VLP FL (low dose, no adjuvant)
ELISA Titre log10 OD50%
5.00
4.00
3.00
2.00
1.00
0.00
-7 0 7 14 21 28 35
Day
A - 1.52 log10 TCID50/mL (IFI) Souriou
A 1.0 log10 TCID50/ml (HA) Bari
C (VLP FL)

FIG. 8

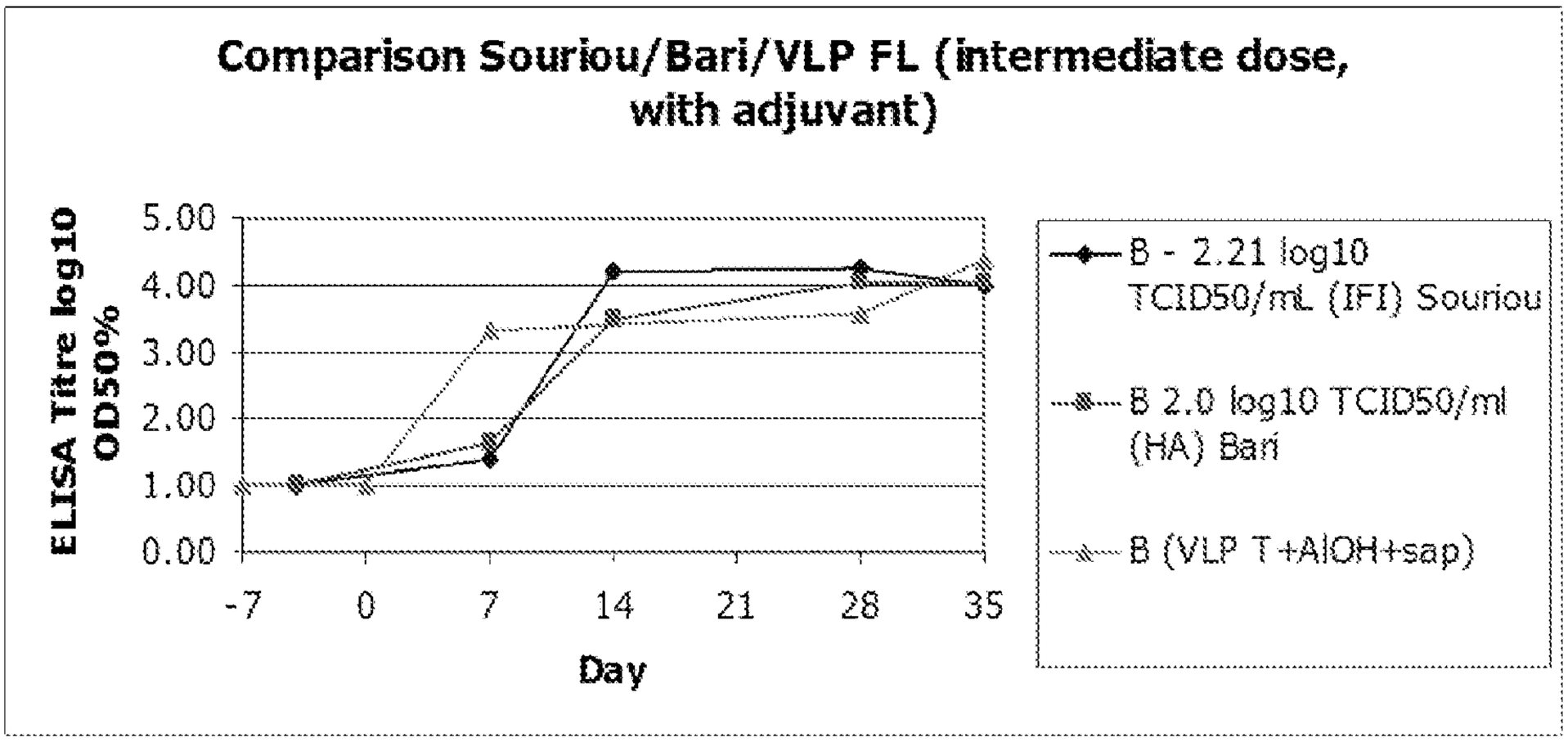

Comparison Souriou/Bari/VLP FL (intermediate dose, with adjuvant)
ELISA Titre log10 OD50%
5.00
4.00
3.00
2.00
1.00
0.00
-7
0
7
14
21
28
35
Day
B - 2.21 log10 TCID50/mL (IFI) Souriou
B 2.0 log10 TCID50/ml (HA) Bari
B (VLP T+AlOH+sap)

FIG. 9

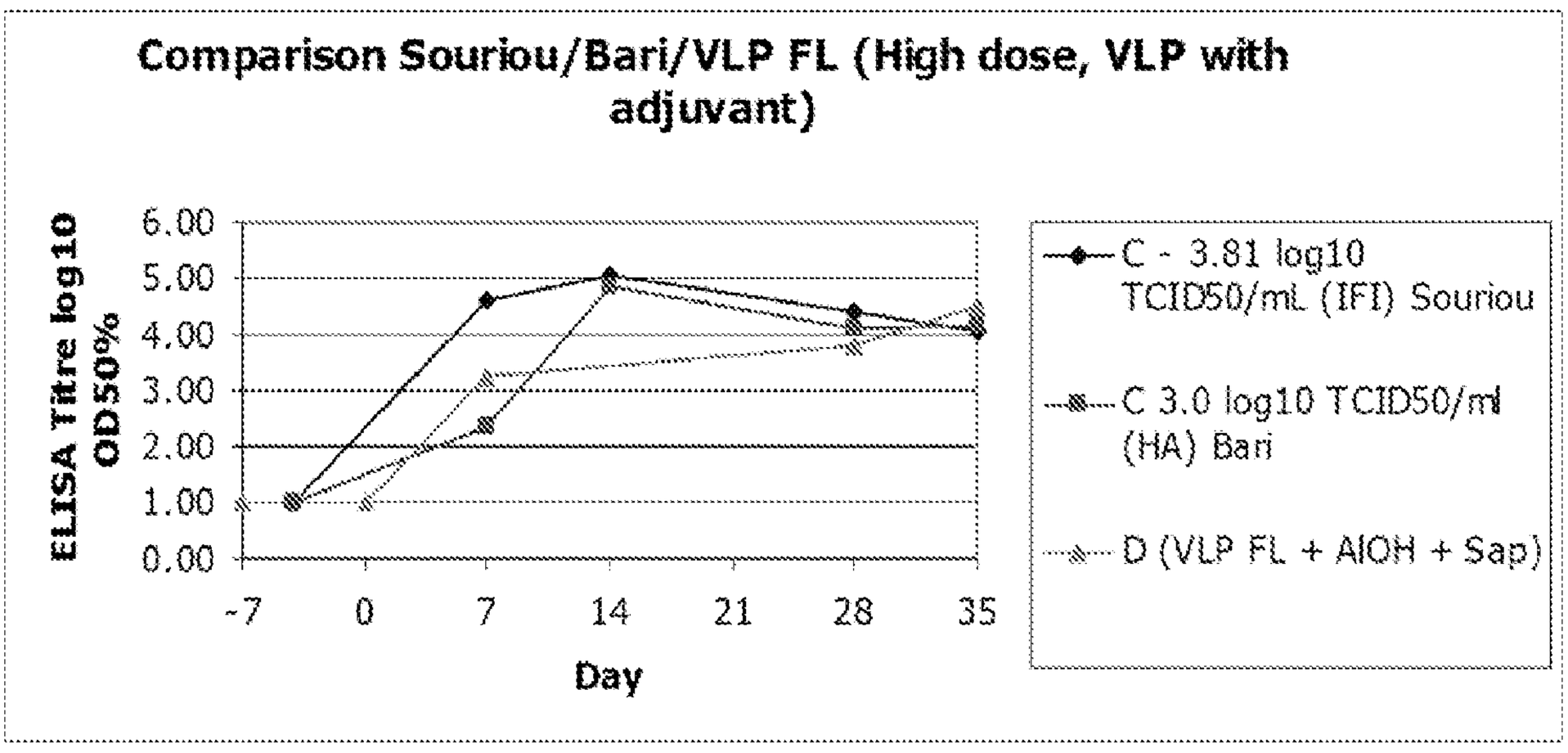

Comparison Souriou/Bari/VLP FL (High dose, VLP with adjuvant)
ELISA Titre log10 OD50%
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-7
0
7
14
21
28
35
Day
C - 3.81 log10 TCID50/mL (IFI) Souriou
C 3.0 log10 TCID50/ml (HA) Bari
D (VLP FL + AlOH + Sap)

FIG. 10

```
SEQ 1   MSDGAVQPDGGQPAVRNERATGSGNGSGGGGGGGSGGVGISTGTFNNQTEFKFLENGWVE 60
SEQ 3   MSDGAVQPDGGQPAVRNERATGSGNGSGGGGGGGSGGVGISTGTFNNQTEFKFLENGWVE 60
SEQ 4   MSDGAVQPDGGQPAVRNERATGSGNGSGGGGGGGSGGVGISTGTFNNQTEFKFLENGWVE 60
SEQ 6   ------MLKGGQPAVRNERATGSGNGSGGGGGGGSGGVGISTGTFNNQTEFKFLENGWVE 54
                .*************************************************

SEQ 1   ITANSSRLVHLNMPESENYRRVVVNNLDKTAVNGNMALDDTHAQIVTPWSLVDANAWGVW 120
SEQ 3   ITANSSRLVHLNMPESENYRRVVVNNLDKTAVNGNMALDDTHAQIVTPWSLVDANAWGVW 120
SEQ 4   ITANSSRLVHLNMPESENYRRVVVNNLDKTAVNGNMALDDTHAQIVTPWSLVDANAWGVW 120
SEQ 6   ITANSSRLVHLNMPESENYRRVVVNNLDKTAVNGNMALDDTHAQIVTPWSLVDANAWGVW 114
        ************************************************************

SEQ 1   FNPGDWQLIVNTMSELHLVSFEQEIFNVVLKTVSESATQPPTKVYNNDLTASLMVALDSN 180
SEQ 3   FNPGDWQLIVNTMSELHLVSFEQEIFNVVLKTVSESATQPPTKVYNNDLTASLMVALDSN 180
SEQ 4   FNPGDWQLIVNTMSELHLVSFEQEIFNVVLKTVSESATQPPTKVYNNDLTASLMVALDSN 180
SEQ 6   FNPGDWQLIVNTMSELHLVSFEQEIFNVVLKTVSESATQPPTKVYNNDLTASLMVALDSN 174
        ************************************************************

SEQ 1   NTMPFTPAAMRSETLGFYPWKPTIPTPWRYYFQWDRTLIPSHTGTSGTPTNIYHGTDPDD 240
SEQ 3   NTMPFTPAAMRSETLGFYPWKPTIPTPWRYYFQWDRTLIPSHTGTSGTPTNIYHGTDPDD 240
SEQ 4   NTMPFTPAAMRSETLGFYPWKPTIPTPWRYYFQWDRTLIPSHTGTSGTPTNIYHGTDPDD 240
SEQ 6   NTMPFTPAAMRSETLGFYPWKPTIPTPWRYYFQWDRTLIPSHTGTSGTPTNIYHGTDPDD 234
        ************************************************************

SEQ 1   VQFYTIENSVPVHLLRTGDEFATGTFFFDCKPCRLTHTWQTNRALGLPPFLNSLPQAEGG 300
SEQ 3   VQFYTIENSVPVHLLRTGDEFATGTFFFDCKPCRLTHTWQTNRALGLPPFLNSLPQAEGG 300
SEQ 4   VQFYTIENSVPVHLLRTGDEFATGTFFFDCKPCRLTHTWQTNRALGLPPFLNSLPQAEGG 300
SEQ 6   VQFYTIENSVPVHLLRTGDEFATGTFFFDCKPCRLTHTWQTNRALGLPPFLNSLPQAEGG 294
        ************************************************************

SEQ 1   TNFGYIGVQQDKRRGVTQMGNTNYITEATIMRPAEVGYSAPYYSFEASTQGPFKTPIAAG 360
SEQ 3   TNFGYIGVQQDKRRGVTQMGNTNYITEATIMRPAEVGYSAPYYSFEASTQGPFKTPIAAG 360
SEQ 4   TNFGYIGVQQDKRRGVTQMGNTNYITEATIMRPAEVGYSAPYYSFEASTQGPFKTPIAAG 360
SEQ 6   TNFGYIGVQQDKRRGVTQMGNTNYITEATIMRPAEVGYSAPYYSFEASTQGPFKTPIAAG 354
        ************************************************************

SEQ 1   RGGAQTDENQAADGDPRYAFGRQHGQKTTTTGETPERFTYIAHQDTGRYPEGDWIQNINF 420
SEQ 3   RGGAQTDENQAADGDPRYAFGRQHGQKTTTTGETPERFTYIAHQDTGRYPEGDWIQNINF 420
SEQ 4   RGGAQTDENQAADGDPRYAFGRQHGQKTTTTGETPERFTYIAHQDTGRYPEGDWIQNINF 420
SEQ 6   RGGAQTDENQAADGDPRYAFGRQHGQKTTTTGETPERFTYIAHQDTGRYPEGDWIQNINF 414
        ************************************************************

SEQ 1   NLPVTEDNVLLPTDPIGGKTGINYTNIFNTYGPLTALNNVPPVYPNGQIWDKEFDTDLKP 480
SEQ 3   NLPVTEDNVLLPTDPIGGKTGINYTNIFNTYGPLTALNNVPPVYPNGQIWDKEFDTDLKP 480
SEQ 4   NLPVTEDNVLLPTDPIGGKTGINYTNIFNTYGPLTALNNVPPVYPNGQIWDKEFDTDLKP 480
SEQ 6   NLPVTEDNVLLPTDPIGGKTGINYTNIFNTYGPLTALNNVPPVYPNGQIWDKEFDTDLKP 474
        ************************************************************

SEQ 1   RLHVNAPFVCQNNCPGQLFVKVAPNLTNEYDPDASANMSRIVTYSDFWWKGKLVFKAKLR 540
SEQ 3   RLHVNAPFVCQNNCPGQLFVKVAPNLTNEYDPDASANMSRIVTYSDFWWKGKLVFKAKLR 540
SEQ 4   RLHVNAPFVCQNNCPGQLFVKVAPNLTNEYDPDASANMSRIVTYSDFWWKGKLVFKAKLR 540
SEQ 6   RLHVNAPFVCQNNCPGQLFVKVAPNLTNEYDPDASANMSRIVTYSDFWWKGKLVFKAKLR 534
        ************************************************************

SEQ 1   ASHTWNPIQQMSINVDNQFNYVPSNIGGMKIVYEKSQLAPRKLY 584
SEQ 3   ASHTWNPIQQMSINVDNQFNYVPSNIGGMKIVYEKSQLAPRKLY 584
SEQ 4   ASHTWNPIQQMSINVDNQFNYVPSNIGGMKIVYEKSQLAPRKLY 584
SEQ 6   ASHTWNPIQQMSINVDNQFNYVPSNIGGMKIVYEKSQLAPRKLY 578
        ********************************************
```

FIG. 11

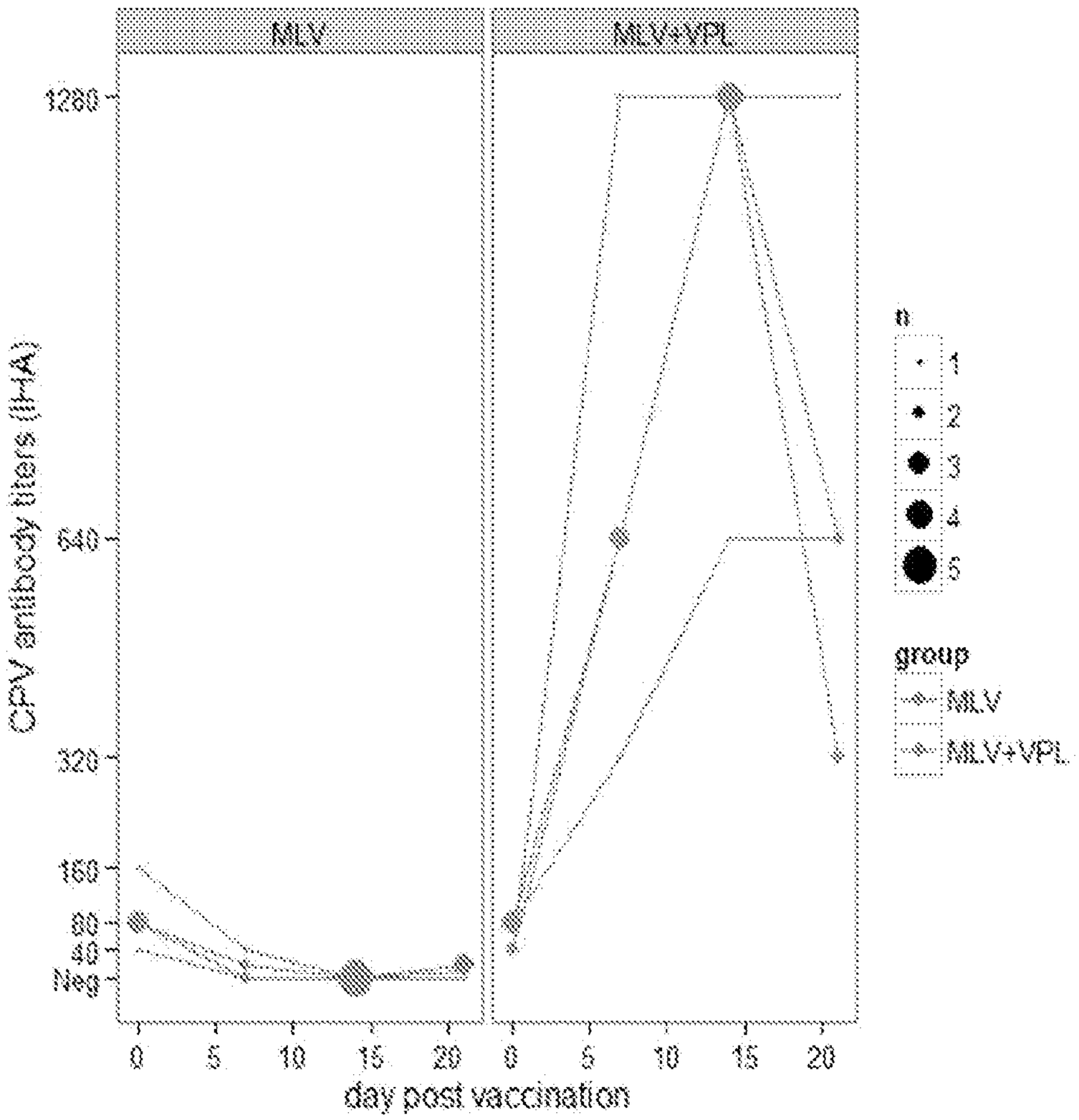

MLV
MLV+VPL
1280
640
320
160
80
40
Neg
CPV antibody titers (IHA)
0
5
10
15
20
day post vaccination
n
1
2
3
4
5
group
MLV
MLV+VPL

FIG. 12

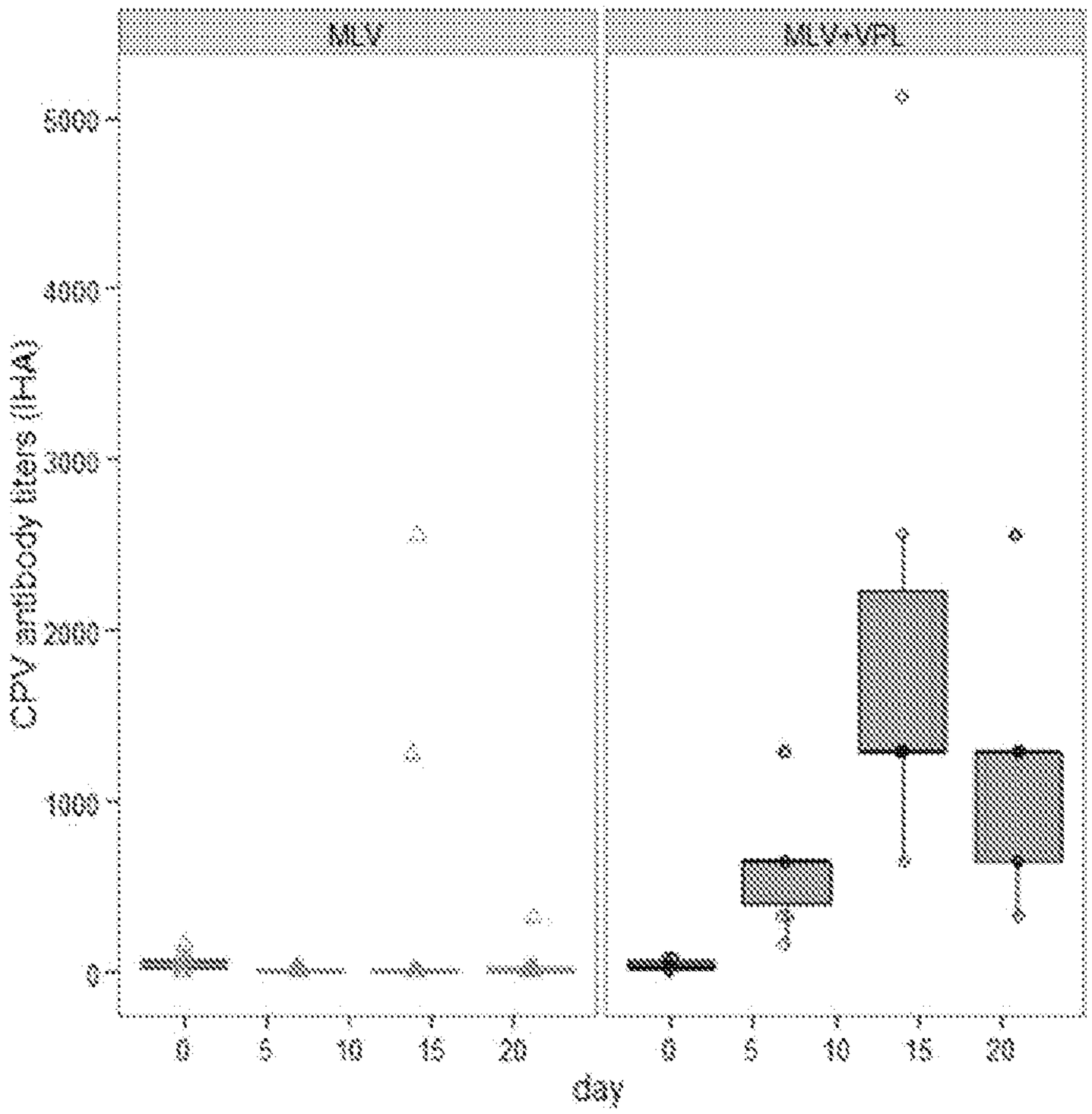

MLV
MLV+VPL
5000
4000
3000
2000
1000
0
CPV antibody titers (IHA)
0
5
10
15
20
day

FIG. 13

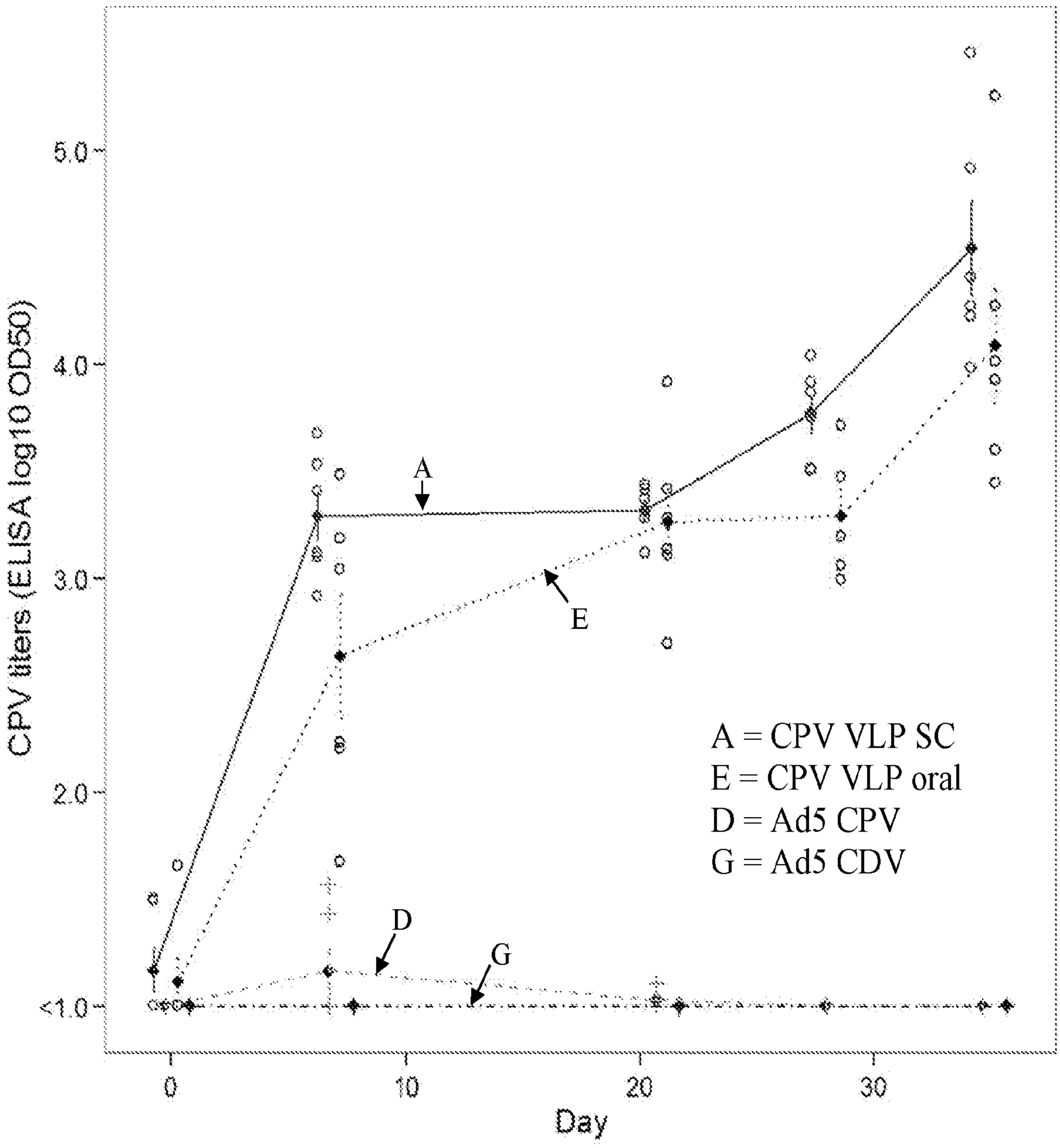

CPV titers (ELISA log10 OD50)
5.0
4.0
3.0
2.0
<1.0
0
10
20
30
Day
A
E
D
G
A = CPV VLP SC
E = CPV VLP oral
D = Ad5 CPV
G = Ad5 CDV

FIG. 14

Example 7: % Responders

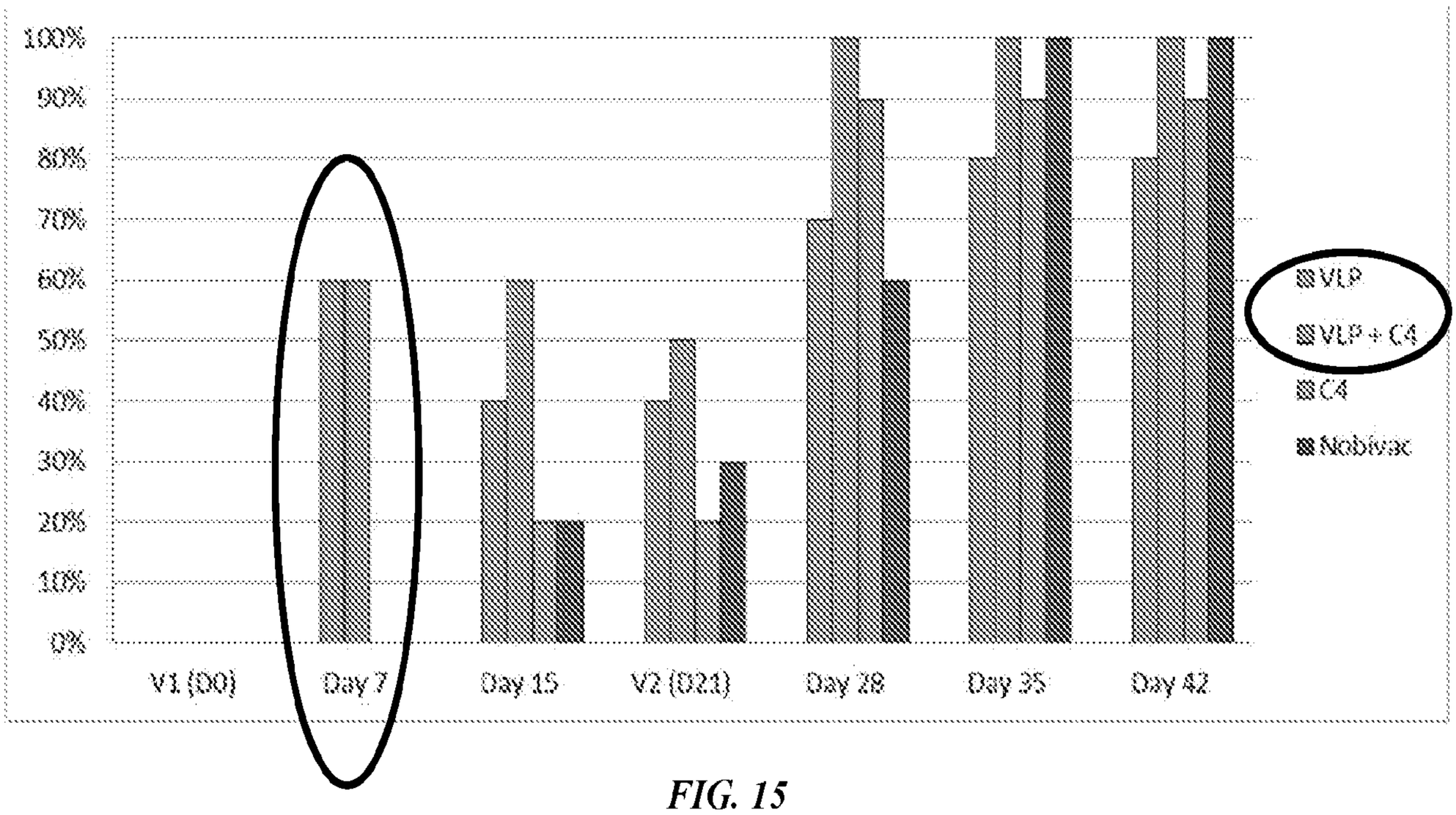


FIG. 15

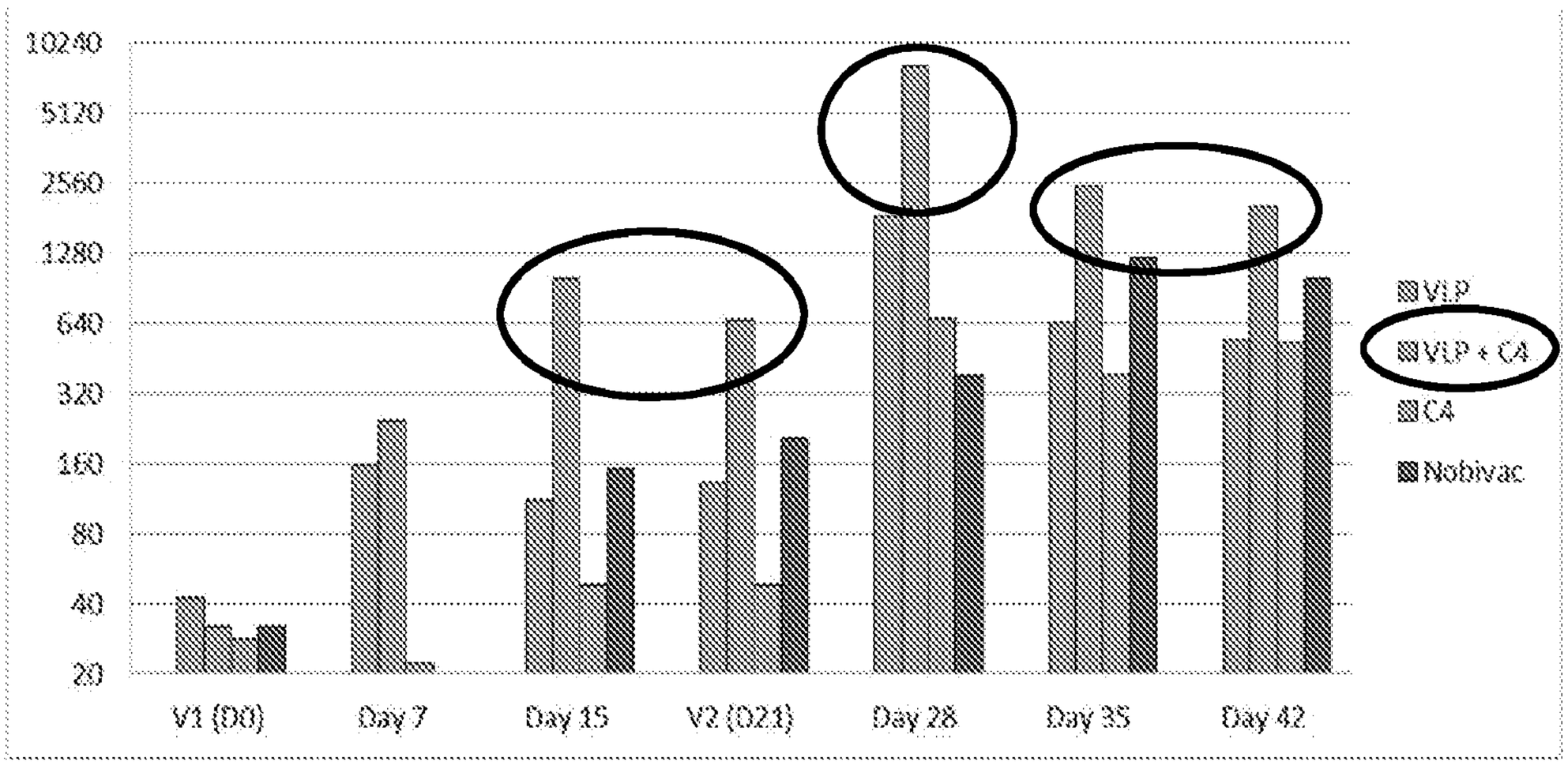


FIG. 16

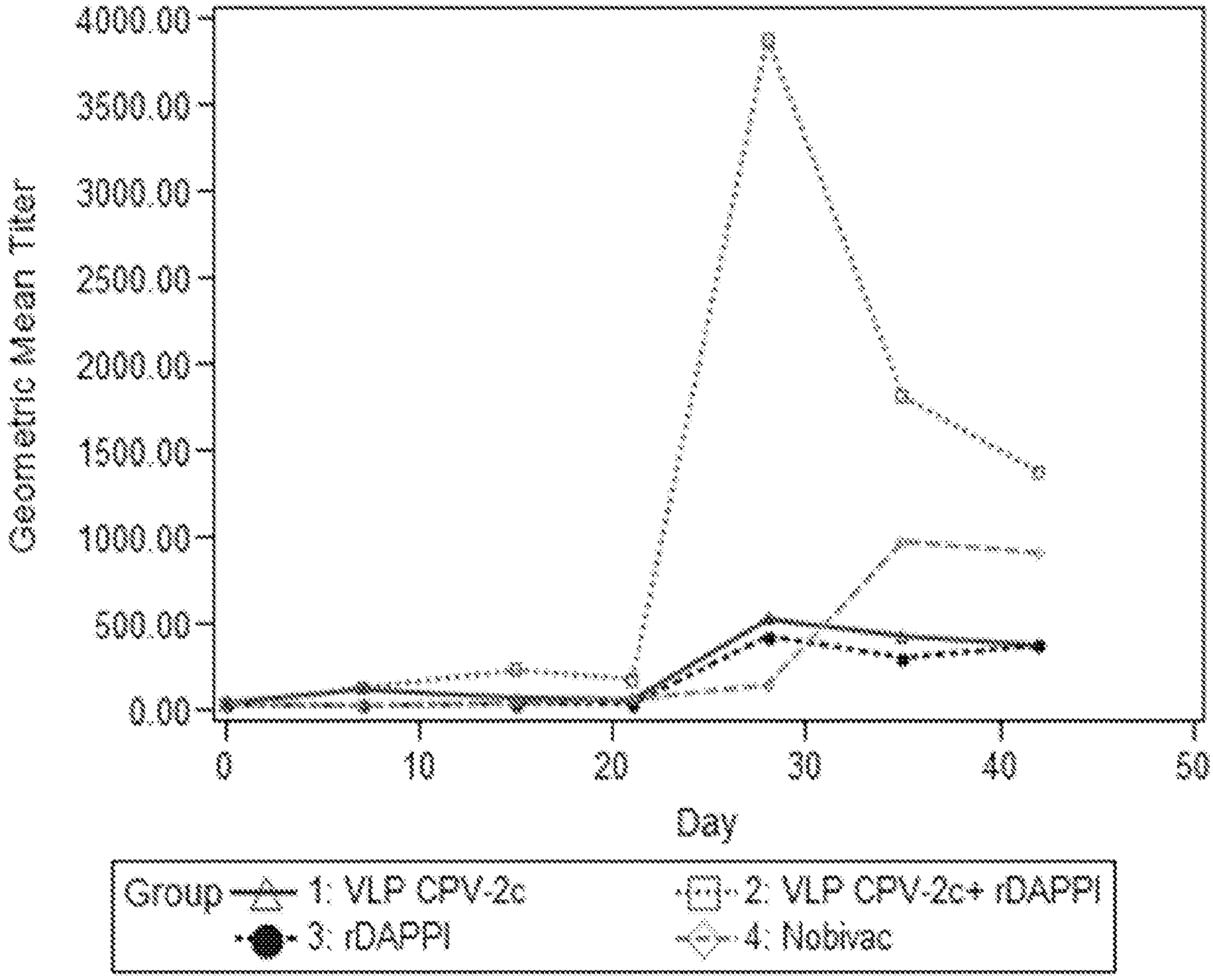

Geometric Mean Titer
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
0
10
20
30
40
50
Day
Group
1: VLP CPV-2c
2: VLP CPV-2c+ rDAPPI
3: rDAPPI
4: Nobivac

FIG. 17

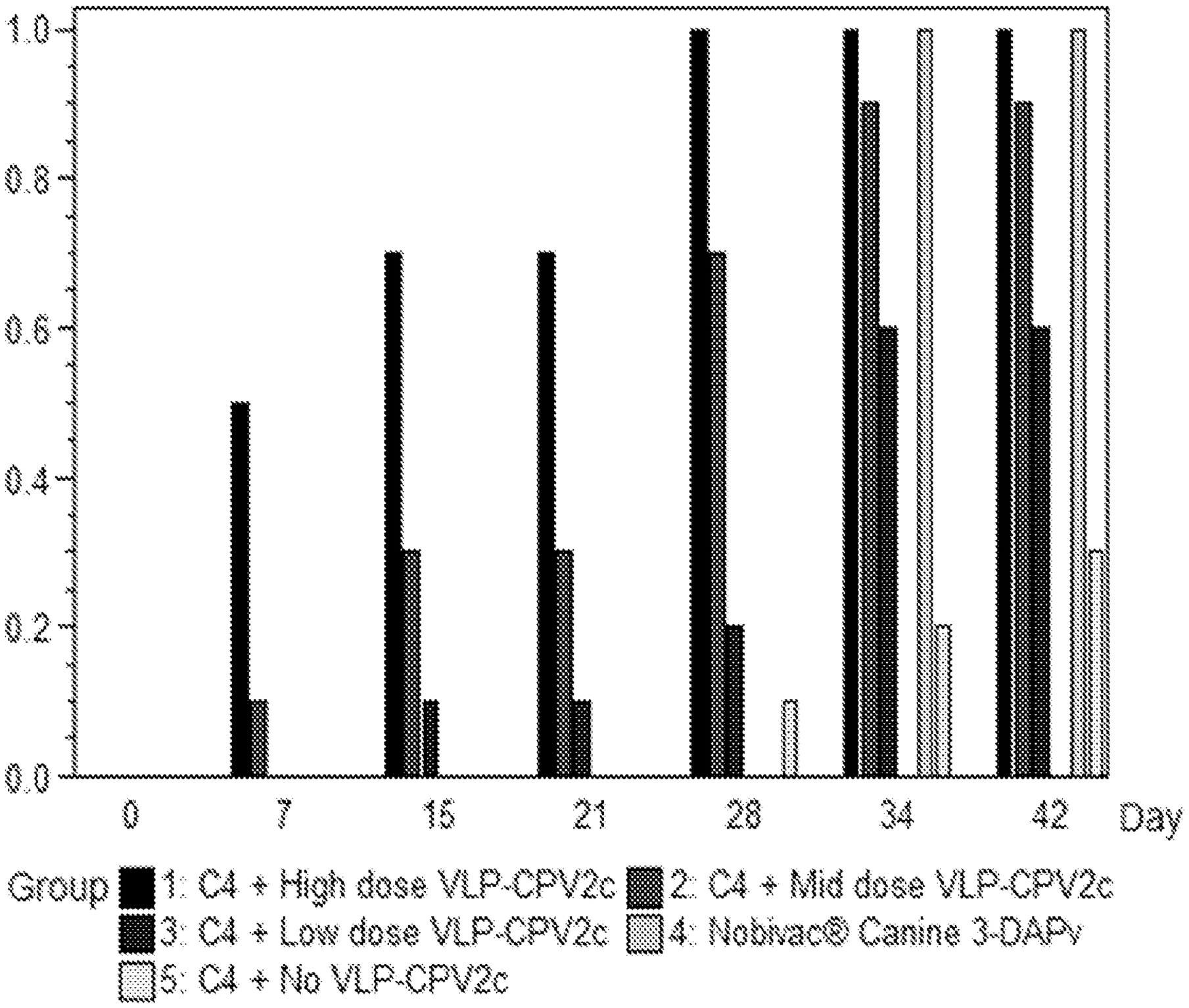
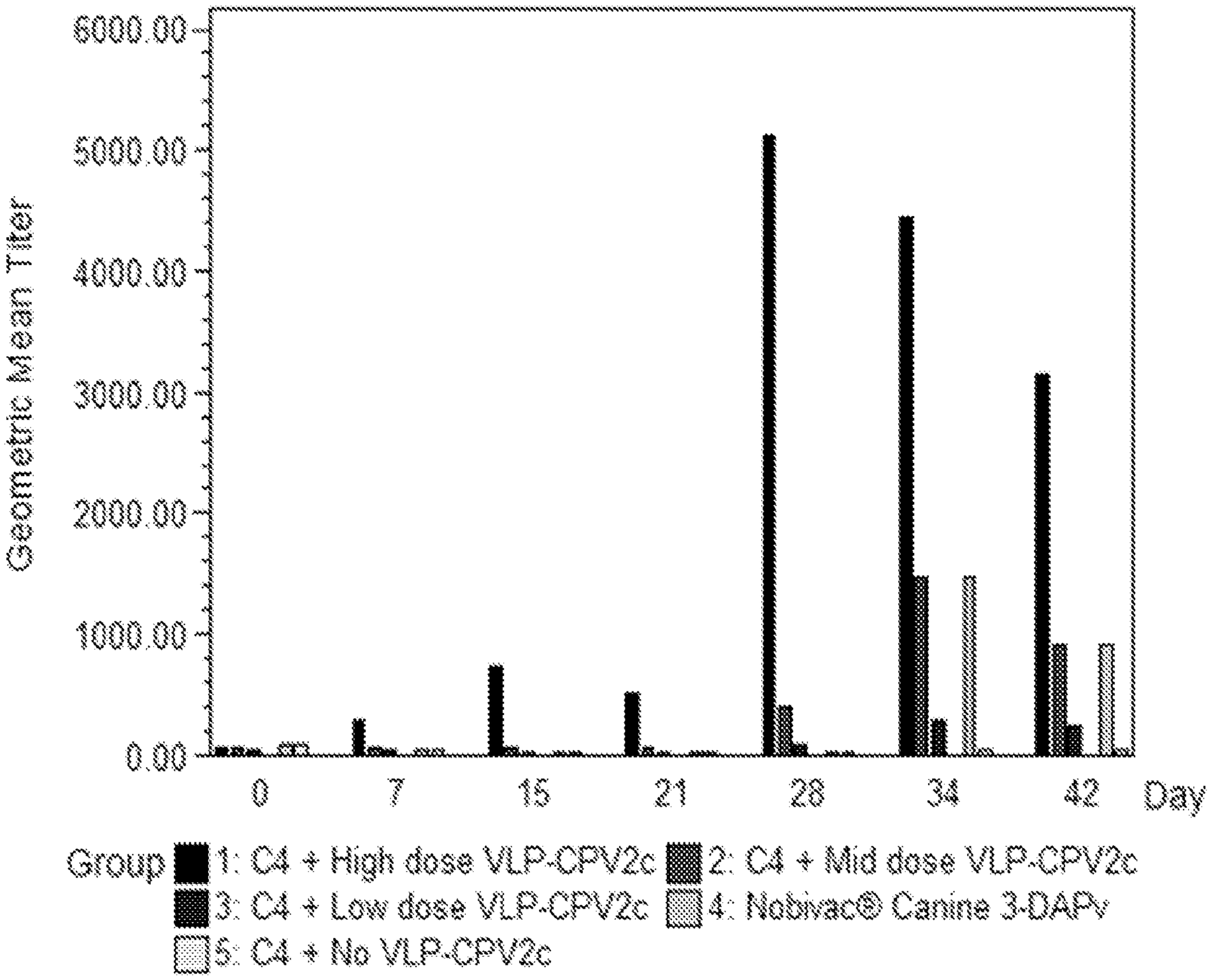

Percentage
0,0
0,2
0,4
0,6
0,8
1,0
0
7
15
21
28
34
42
Day
Group
1: C4 + High dose VLP-CPV2c
2: C4 + Mid dose VLP-CPV2c
3: C4 + Low dose VLP-CPV2c
4: Nobivac® Canine 3-DAPy
5: C4 + No VLP-CPV2c

FIG. 18



V1 - Day 0; V2 - Day 21

FIG. 19