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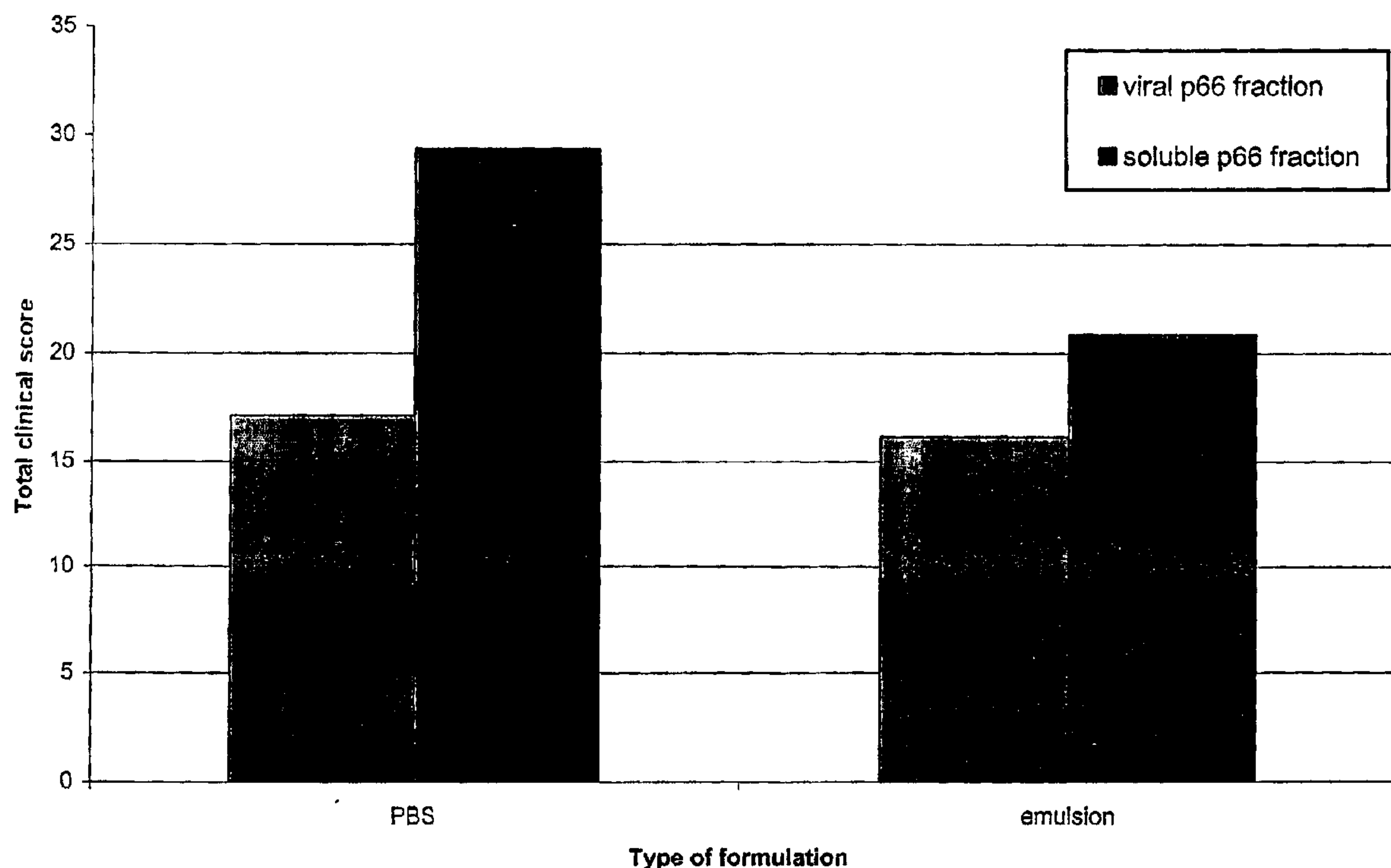
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(54) Titre : VACCINS AMELIORES A FCV INACTIVE
(54) Title: IMPROVED INACTIVATED FELINE CALICIVIRUS VACCINES

Means of the total clinical scores per type of vaccines



(57) Abrégé/Abstract:

The present invention relates to improved inactivated feline calicivirus (FCV) vaccines. The invention also provides a process for producing stabilized inactivated FCV, and the use of such stabilized inactivated FCV, in the production of FCV immunogenic compositions. The invention further provides methods of inducing an immune response in an animal of the Felidae family, preferably a cat, using the immunogenic compositions according to the invention.

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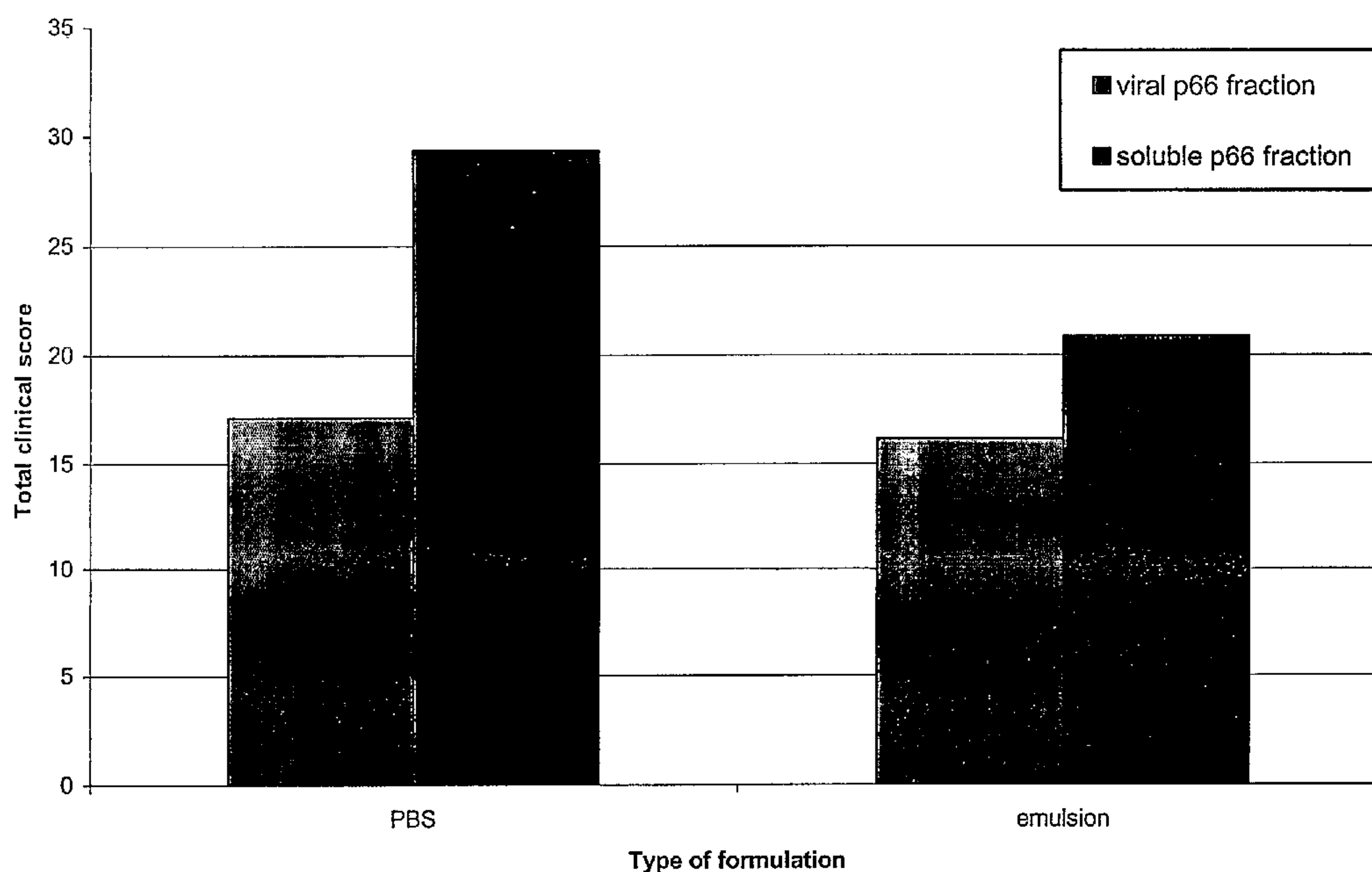
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(54) Title: IMPROVED INACTIVATED FCV VACCINES

Means of the total clinical scores per type of vaccines



(57) Abstract: The present invention relates to improved inactivated feline calicivirus (FCV) vaccines. The invention also provides a process for producing stabilized inactivated FCV, and the use of such stabilized inactivated FCV, in the production of FCV immunogenic compositions. The invention further provides methods of inducing an immune response in an animal of the Felidae family, preferably a cat, using the immunogenic compositions according to the invention.

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TITLE OF THE INVENTION**IMPROVED INACTIVATED FELINE CALICIVIRUS VACCINES****CROSS-REFERENCE TO RELATED APPLICATIONS**

- 5 This application claims priority from U.S. Provisional Patent Application Serial No. 60/573,849, filed on January 21, 2004.

15 **FIELD OF THE INVENTION**

 The present invention relates to improved inactivated and stabilized feline calicivirus (FCV) immunogenic compositions. The invention also provides a process for producing inactivated and stabilized FCV, and the use of such inactivated and stabilized FCV in the production of FCV immunogenic compositions. The invention further provides
20 methods of inducing immune responses in animals of the Felidae family, preferably a cat, using the immunogenic compositions according to the invention.

BACKGROUND OF THE INVENTION

 Feline calicivirus (FCV) was first described in 1957 (Fastier, L.B. (1957) Am. J. Vet. Res. 18: 382-389). FCV affects a large number of animals of the Felidae family, with
25 FCV being carried by up to 15 to 20% of clinically healthy domestic cats (Coutts et al (1994) Vet. Rec. 135: 555-556; Ellis, T.M. (1981) Australian Vet. J. 57: 115-118; Harbour et al. (1991) Vet. Rec. 128: 77-80; Reubel et al, (1992) Feline Dentistry 22: 1347-1360). Calicivirus often occurs with another upper respiratory infection, such as feline herpes virus
30 (FHV), rhinotracheitis virus, or chlamydiosis in domestic cats and wild felids. FCV is transmitted horizontally and there is no evidence of vertical transmission from the mother to its kitten during gestation (Johnson, R.P. (1984) Res. Vet. Sci. 31: 114-119). FCV transmission occurs primarily through contact between infected animals and healthy

animals or by the airways during sneezing (Wardley R C. (1976) Arch. Virol 52: 243-249). FCV is quite resistant to a number of disinfecting agents and thus can also be spread in the absence of direct contact.

FCV is generally known to cause disease characterized by conjunctivitis, rhinitis, tracheitis, pneumonia and by vesicularization/ulceration of the epithelium of the oral cavity. Other symptoms include fever, anorexia, lethargy, stiff gait, and sometimes nasal and ocular discharge. FCV usually affects the throat, and sometimes the lungs; it can also infect the intestines and has been isolated from feces. After an initial phase of hyperthermia, these respiratory diseases are generally followed by buccal ulcerations (palate, tongue, lips, and nose), rhinitis, conjunctivitis, and possibly anorexia and asthenia. FCV can also cause pneumonia, enteritis, and articular pain (lameness syndrome). Morbidity can be high and recovery is followed by a prolonged carrier state. The type of disease symptoms caused by FCV depends on the FCV strain; some strains will produce little or no disease, while other more virulent strains cause pyrexia, anorexia, depression or pneumonia. One particular strain can cause ulcers on the paws as well as in the mouth.

Feline calicivirus of the *Caliciviridae* family is a non-enveloped virus, comprising a single-stranded positive-sense RNA genome that is polyadenylated and is about 7.7 kilobases in size (Radford et al. (1997) Proc. 1st Int. Symp. Caliciviruses ESVV 93-99). The FCV capsid is comprised of a single major capsidal protein of 66 kDa (kilodalton), the p66 protein. The molecular biology of the caliciviruses was reviewed by Clarke and Lambden (1997) J. Gen. Virol. 8: 291-301. Like many RNA viruses, large heterogeneity exists within the viral population of FCV. The antigenic variations, demonstrated since the beginning of the 1970s by cross-serum neutralization experiments, make it possible to classify the FCVs into several viral strains or quasi-species (Radford et al. (1997) Proc. 1st Int. Symp. Caliciviruses ESVV 93-99). Several FCV strains have been identified and isolated, in particular strain F9 (deposited with the American Type Culture Collection or ATCC under the accession number VR-782), strain 2280 (ATCC VR-2057), strain KCD (ATCC VR-651), strain CFI (ATCC VR-654), strain FCV-LLK and strain FCV-M8.

Due to the long carrier state after recovery from an FCV infection, as well as FCV resistance to disinfecting agents, FCV is highly contagious and easily spread, particularly among groups of animals in close proximity, for example, in animal shelters or veterinary clinics. Therefore, there has been and remains a strong need in the art for effective FCV vaccines.

Vaccination against FCV was introduced at the end of the 1970s, using attenuated FCV strains, primarily strain F9 isolated in the USA in 1958 by Bittle (Bittle et al. (1960) Am. J. Vet. Res. 21: 547-550) or strains derived from F9 by passage *in vitro* or *in vivo* ("F9-like").

5 Vaccines that are based on inactivated FCV strains are also available. These vaccines mainly use strains 255 and 2280, which were isolated in the USA in 1970 in a cat with pneumonia (Kahn and Gillespie, (1970) Cornell Vet. 60: 669-683; Povey et al. (1980) J. Am. Vet. Med. Assoc. 177: 347-350) and in 1983 in a cat suffering from lameness, respectively (Pedersen et al. (1983) Fel. Prac. 13: 26-35; Pedersen N.C. and Hawkins K.F. 10 (1995) Vet Microbiol. 47: 141-156).

Because of antigenic drift over time, antisera produced against vaccine strains isolated in the 1960's and 1970s, such as strains F9, 255 or 2280, neutralize only a few isolates of the strains isolated in the 1990s. For example, the anti-F9 serum neutralizes 43% of the American isolates of the period 1990-1996, in contrast to its ability to neutralize 56% 15 of the isolates of the period 1980-89 and 86% of the isolated of the period 1958-79, and only 10% of the English isolates of the period 1990-96 (Lauritzen et al. (1997) Vet. Microbiol. 56: 55-63). Accordingly, attenuated and inactivated vaccines from old FCV strains at present no longer offer sufficient protection against recently isolated FCV strains.

US Patent No. 6,534,066 describes the use of new strains of FCV for the production 20 of FCV vaccines. Among these strains, FCV strain 431 (deposited at the CNMC under the accession number I-2166) is an isolate the antiserum for which was shown to neutralize a large number of heterologous field isolates. This is in contrast to the historical vaccine strains, such as F9 and FCV-225, whose antisera neutralize very limited numbers of recent field FCV isolates.

25 The majority of the commercial FCV vaccines are attenuated vaccines. Only few inactivated vaccines are available, all of them containing an adjuvant. Povey and coworkers (Povey et al. (1978) Feline Practice 8(3): 35-42) describe a formalin inactivated and adjuvanted FCV preparation used in kittens.

When a vaccine is inactivated, the inactivation is usually performed by chemical 30 treatment with agents such as formalin, or formaldehyde, β -propiolactone, ethyleneimine, binary ethyleneimine in the presence or absence of heat treatment. In U.S. Patent No. 6,534,066, for example, FCV is inactivated by ethyleneimine and adjuvanted with an oil-in-water emulsion. U.S. Patent No. 6,355,246 describes attenuated FCV vaccines isolated

from feline urine. Inactivation of FCV can be achieved by treatment with formaldehyde or binary ethyleneimine (BEI). Notably, U.S. Patent No. 6,355,246 does not direct or provide the skilled artisan with methods of inactivating FCV.

5 The inactivated vaccines heretofore used against FCV require or prefer adjuvants in the vaccine or immunogenic composition to improve the immune response and to induce better protection against heterologous FCV strains emerging in the cat population. However adjuvanted vaccines induce a higher rate of local adverse reactions than non-adjuvanted ones (Gobar et al., (2002) JAVMA 220(10): 1477-1482) and thereby increase the risk of vaccine-associated fibrosarcomas at the injection site (Baker R.J. (1998) Feline Practice
10 26(5): 18-20).

Presently, non-adjuvanted FCV vaccines are modified live vaccines, usually containing the F9 strain. The residual virulence of FCV F9 has been demonstrated by several studies in post-vaccinal calicivirosis (Dawson et al., (1993) Vet. Rec. 132: 346-350). Although only one FCV serotype exists, high antigenic variation between FCV isolates has
15 been observed and new field isolates are regularly identified (Lauritzen, et al. (1997) Vet. Microbiol. 56: 55-63). This high antigenic variation often leads to increased failure rates of FCV neutralization by antisera based on an F9 vaccine. Furthermore, FCV modified live strains are implicated in the emergence of new antigenic variants in the field (Radford et al., (1997) Vaccine 15(12/13): 1451-1458). The safety of these modified live vaccines is
20 therefore questionable.

Consequently, there remains a need in the art for efficacious, inactivated non-adjuvanted FCV vaccines or immunogenic compositions with improved safety and which are capable of inducing a strong immune response against heterologous FCV strains.

25 **SUMMARY OF THE INVENTION**

Previous inactivated FCV vaccines or immunogenic compositions usually comprise a mixture of FCV virions and protein fractions resulting from the degradation of the viral capsid. The present inventors have found that for a non-adjuvanted vaccine or immunogenic composition, it is essential to limit the degradation of the viral capsid and to retain intact
30 virions as much as possible.

It has been surprisingly found that subjecting FCV to treatment by an inactivating agent that inactivates the virus and to treatment with formaldehyde that may stabilize the virion allows one to obtain an inactivated FCV composition having good efficacy, even in

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the absence of any adjuvant. Without wanting to be bound to any particular theory, it is believed that the presence of formaldehyde stabilizes the viral capsids. The increased stability of the viral capsid results in enhanced stability of the FCV vaccine or immunogenic composition during long-term storage and before administration to the animal. Other chemical compounds acting similarly to stabilize the viral capsid may be used in place of formaldehyde.

A first aspect of the present invention provides an inactivated, stabilized, non-adjuvanted immunogenic composition against feline calicivirus (FCV), comprising an FCV inactivated by one or more inactivating agents and stabilized by an aldehyde compound, wherein the aldehyde compound comprises a linear C1-C5 alkyl chain, and wherein the immunogenic composition is in admixture with an acceptable vehicle or excipient.

Preferably, the excipient or vehicle is veterinarily acceptable. In another embodiment, the immunogenic composition is freeze-dried and is in admixture with a freeze-drying excipient or vehicle.

The preferred inactivating agents can be selected from the group consisting of ethyleneimine, acetyleneimine, propyleneimine, and β -propiolactone. Preferably, the inactivating agent is ethyleneimine.

Thus, in a particular embodiment, the invention relates to an inactivated, stabilized, non-adjuvanted immunogenic composition against feline calicivirus (FCV), comprising an FCV inactivated by one or more inactivating agents and stabilized by an aldehyde compound, wherein the aldehyde compound comprises a linear C1-C5 alkyl chain, and wherein the immunogenic composition is in admixture with an acceptable excipient or vehicle and wherein the inactivating agents are selected from the group consisting of ethyleneimine, acetyleneimine, propyleneimine, and β -propiolactone.

When ethyleneimine is used as the inactivating agent, the ethyleneimine is present from about 0.5 mM to about 20 mM, preferably from about 1 mM to about 10 mM.

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When the aldehyde compound comprises a linear C1 alkyl chain, the aldehyde compound comprises one aldehyde group. When the aldehyde compound comprises a linear C2-C5 alkyl chain, the aldehyde compound comprises two aldehyde groups. In an alternative embodiment, one of the two aldehyde groups can
5 be replaced by a ketone or an epoxy group. The aldehyde compound can be selected from the group consisting of formaldehyde, glycidaldehyde, glutaraldehyde, glyoxal, or methylglyoxal. When the aldehyde compound is formaldehyde, the formaldehyde is present from about 0.05 g/l to about 0.8 g/l. Preferably, the formaldehyde is present from about 0.1 g/l to about 0.5 g/l.

10 A further embodiment further comprises a neutralizing compound comprising thiol groups (e.g. thiosulfate and cysteine). The present invention also comprises at least one FCV strain, wherein at least one or all of the FCV strains are inactivated and stabilized. The FCV strain can be selected from the group consisting of FCV F9, FCV 255, FCV 2280, FCV 431, FCV G1, FCV LLK, FCV KCD, FCV CFI,
15 FCV M8, and FCV US 100869 (ATCC Accession No. FCV PTA 5930).

In another embodiment, the immunogenic compositions of the invention further comprise at least one non-FCV immunogen from a feline pathogen, which can be selected from the group consisting of feline herpesvirus (FHV), feline leukemia virus (FeLV), feline panleukopenia virus (FPV), feline infectious peritonitis virus
20 (FIPV), feline immunodeficiency virus (FIV), rabies virus, and Chlamydia. Preferably, the at least one non-FCV immunogen from a feline pathogen comprises a live attenuated microorganism or a recombinant vector that expresses at least one non-FCV immunogen from a feline pathogen.

A second aspect of the invention provides a process for inactivating and
25 stabilizing FCV, comprising the steps of reacting FCV with an inactivating agent and an aldehyde compound, wherein the aldehyde compound comprises a linear C1-C5 alkyl chain, and recovering the inactivated and stabilized FCV. A preferred embodiment recovers the inactivated and stabilized FCV by size exclusion chromatography, ultracentrifugation, and selective precipitation.

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In an embodiment, the invention relates to a process for inactivating and stabilizing FCV, comprising the steps of reacting FCV with an inactivating agent and an aldehyde compound, wherein the aldehyde compound comprises a linear C1-C5 alkyl chain, and wherein the inactivating agent is selected from the group
5 consisting of ethyleneimine, acetyleneimine, propyleneimine, and β -propiolactone, and recovering the inactivated and stabilized FCV.

In another aspect of the present invention, a process for producing inactivated, stabilized, non-adjuvanted immunogenic composition against FCV for long-term storage is provided, comprising mixing the inactivated and stabilized FCV
10 of the invention in an amount sufficient to induce an immune response to FCV with a freeze-drying excipient, and freezing the composition.

Yet another aspect provides a process for producing an inactivated, stabilized, non-adjuvanted immunogenic composition against FCV, comprising mixing the inactivated and stabilized FCV of the invention in amount sufficient to induce an
15 immune response to FCV with a veterinarily acceptable excipient or vehicle.

Also provided in the present invention are methods of inducing an immune response in a Felidae against FCV, comprising administering to the Felidae the inactivated, stabilized, non-adjuvanted immunogenic compositions of the invention, thereby inducing an immune response in the Felidae.

20 A further aspect provides a method of inducing an immune response in a Felidae against FCV and at least one non-FCV immunogen from a feline pathogen, comprising administering to the Felidae the inactivated, stabilized, non-adjuvanted immunogenic composition of the invention, and at least one non-FCV immunogen from another feline pathogen, thereby inducing an immune response in the Felidae.

25 In another embodiment, the invention relates to the use of the inactivated, stabilized, non-adjuvanted immunogenic composition as described herein for inducing an immune response in a Felidae against FCV.

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In another embodiment, the invention relates to the use of a combination comprising the inactivated, stabilized, non-adjuvanted immunogenic composition as described herein and at least one non-FCV immunogen from a feline pathogen for inducing an immune response in a Felidae against FCV and the at least
5 one non-FCV immunogen from a feline pathogen.

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These and other embodiments are disclosed or are obvious from and encompassed by, the following Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The following Detailed Description, given by way of example, and not intended to limit the invention to specific embodiments described, may be understood in conjunction with the accompanying Figures, in which:

Figure 1 is a graph showing the mean of the total clinical score during the two weeks post-challenge per type of composition administered (according to Example 3).

10 Figure 2 is a graph showing the mean of the maximum clinical score for an observation on a cat during the two weeks post-challenge per type of composition administered (according to Example 3).

Figure 3 is a graph showing the mean anti-FCV255 neutralizing antibody titers (expressed as $\log_{10}$) per group and day (according to Example 4).

15 Figure 4 is a graph showing the global scores per group (according to Example 4).

Figure 5 is a graph showing the mean FCV excretion after challenge per group and day, expressed as $\log_{10}$ CCID₅₀/ml (according to Example 4).

DETAILED DESCRIPTION OF THE INVENTION

20 It is noted that in this disclosure and particularly in the claims, terms such as “comprises”, “comprised”, “comprising” and the like can have the meaning, e.g., “includes”, “included”, “including”, and the like; and that terms such as “consisting essentially of” and “consists essentially of” can have the meaning, e.g., that they allow for elements not explicitly
25 recited, but exclude elements that are found in the prior art or that affect a basic or novel characteristic of the invention.

The term “immunogenic composition” covers any composition capable, once administered to the target species under the conditions of the invention, of inducing an immune response directed against FCV. The term “vaccine” is intended to mean a
30 composition capable of inducing effective protection. The target species are the Felidae, preferably cats.

The present invention relates to an inactivated, stabilized, non-adjuvanted FCV immunogenic composition or vaccine comprising FCV that has been subjected to an

inactivating agent and to a stabilizing aldehyde compound. A preferred group of stabilizing compounds are aldehydes formed of which have a linear alkyl C1-C5 chain comprising one aldehyde group when the chain is C1 and two terminal aldehyde groups when the chain is C2-C5, and optionally one aldehyde group may be replaced by a ketone or an epoxy group when the chain is the C2-C5 chain, and the immunogenic composition or vaccine is either freeze-dried in admixture with a freeze drying excipient or vehicle, or in admixture with a veterinarily acceptable excipient or vehicle.

An "inactivating agent" is an agent able to block the multiplication of a virus by an irreversible reaction, mainly, but not limited to, reactions with viral nucleic acids, which does not substantially affect the immunogenic property of the virus. Preferred examples of inactivating agents are ethyleneimine and the amide derivatives (for example acetyleneimine), propyleneimine, β -propiolactone. In a preferred embodiment, the inactivating agent is ethyleneimine.

In a preferred embodiment, the FCV is inactivated by ethyleneimine. The final concentration of ethyleneimine can be from about 0.5 mM to about 20 mM, and preferably from about 1 mM to about 10 mM. The temperature can be from about 2°C to about 40°C, and preferably from about 5°C to about 30°C.

The preferred stabilizing aldehyde compounds react with amino groups (e.g. amino groups on lysine, arginine or histidine amino acids) and hydroxyl groups of protein(s) (e.g. hydroxyl groups on tyrosine amino acids) and can form linkages between two proteins and/or within a protein. The stabilizing aldehyde compound is preferably selected from the group consisting of formaldehyde (or methanal), glycidaldehyde (or 2,3-epoxy-1-propanal), glutaraldehyde (or 1,5-dial-pentane), glyoxal (or 1,2-dial-ethane), methylglyoxal (or pyruvaldehyde). In a preferred embodiment, the stabilizing aldehyde compound is formaldehyde.

When formaldehyde is used as the stabilizing aldehyde, the final concentration may be from about 0.05 g/l to about 0.8 g/l, preferably from about 0.075 g/l to about 0.6 g/l, and more preferably from about 0.1 g/l to about 0.5 g/l. The temperature may be from about 2°C to about 37°C, preferably from about 2°C to about 22°C, and more preferably from about 4°C to about 7°C.

To adjust the stabilization conditions (temperature, concentration of the stabilizing aldehyde compound and duration), quantification of the FCV virions may be performed. Any appropriate technique to quantify virions may be used, for example, an enzyme-linked

immunosorbent assay (ELISA) using a monoclonal or polyclonal antibody specific for the FCV capsid protein. Before ELISA quantification, the virions can be separated from the treated viral culture with techniques known by the skilled artisan, for example size exclusion chromatography, ultracentrifugation on a sucrose gradient, ultracentrifugation on a cesium chloride gradient, and selective precipitation, for example, polyethylene glycol (PEG) precipitation.

The FCV suspension used for the immunogenic composition or vaccine contains preferably from about $10^{8.5}$ to about 10^{11} CCID₅₀ per dose before inactivation, more preferably from about 10^9 to about 10^{10} CCID₅₀ per dose before inactivation. After completion of inactivation and/or stabilization, the inactivating agent and/or the stabilizing aldehyde compound can be removed from the suspension by neutralization methods known by one skilled in the art, for example, by adding neutralizing compounds comprising thiol groups (e.g. thiosulfate, cysteine).

Elimination of the inactivating agent and/or the stabilizing aldehyde compound, or alternatively, recovering the inactivated and stabilized FCV from the suspension can be achieved by techniques known by one skilled in the art, for example, size exclusion chromatography, ultracentrifugation on a sucrose gradient, ultracentrifugation on a cesium chloride gradient, selective precipitation for example polyethylene glycol (PEG) precipitation.

Recovery of the virions from the suspension, after virus inactivation and stabilization, can be achieved concomitantly in the processing step that eliminates the inactivating agent and/or the stabilizing aldehyde. In an alternative embodiment, recovering the inactivated and stabilized virions may be achieved in a discrete step that is not concomitant with the step that eliminates the inactivating agent and/or the aldehyde compound. This step of virion recovery may be achieved by techniques known by one skilled in the art, for example, size exclusion chromatography, ultracentrifugation on a sucrose gradient, ultracentrifugation on a cesium chloride gradient, and selective precipitation, for example, polyethylene glycol (PEG) precipitation.

The immunogenic compositions and vaccines according to the invention may comprise a combination of at least two FCV strains that are inactivated and stabilized, or a combination of at least two FCV strains wherein at least one of the FCV strains is inactivated and stabilized.

Preferably, the FCV strain(s) is/are selected from those recently isolated from the field. Preferred strains include the strains 431 (deposited at the CNCM under the accession number I-2166; or any strain reacting with the monoclonal antibody 44 secreted by the hybridoma deposited at the CNCM under the accession number I-2282; see U.S. Patent No. 6,534,066), FCV G1 (deposited at the CNCM under the accession number I-2167) (CNCM = "Collection Nationale de Cultures de Microorganismes", Pasteur Institute, Paris, France), FCV US 100869 (also known as FCV PTA 5930; deposited at the ATCC on April 22, 2004) (ATCC = "American Type Culture Collection", Manassas, Virginia, USA) and more generally any of the new highly virulent strains described in publications (Pedersen et al. (2000) Vet. Microbiol. 73 : 281-300; Schorr-Evans et al. (2003) JFMS 5 : 217-226; Hurley et al. (2003) Vet. Clin. Small Anim. 33: 759-772). In a preferred embodiment, the immunogenic composition or vaccine comprises inactivated and stabilized FCV 431 (or any strain reacting with the monoclonal antibody 44) and inactivated and stabilized FCV G1. In another preferred embodiment the immunogenic composition or vaccine comprises inactivated and stabilized FCV US 100869 (ATCC Accession No. FCV PTA 5930). Other strains of FCV that can be used in or in addition to the present invention include, but are not limited to, FCV F9, FCV 255, FCV 2280, FCV LLK, FCV KCD, FCV CFI, and FCV M8.

The inactivated and stabilized FCV immunogenic composition or vaccine can be easily combined with live attenuated or inactivated vaccine(s) or immunogenic compositions that is/are used for other feline disease(s). Therefore, another object of the invention is thus a non-adjuvanted combination immunogenic composition or vaccine comprising at least one stabilized and inactivated FCV and at least one non-FCV immunogenic component for inducing in the host an immune response against at least one other feline pathogen, wherein said non-FCV immunogenic component may be an immunogen from another feline pathogen or a recombinant vector expressing this immunogen, wherein the non-adjuvanted combined immunogenic composition or vaccine is either in a freeze-dried in admixture with a freeze-drying excipient or vehicle or in admixture with a veterinarily acceptable vehicle or excipient. The freeze-dried form is preferred.

In a preferred embodiment, the non-adjuvanted combined immunogenic composition or vaccine comprises the non-FCV immunogenic component either in the form of a live attenuated microorganism or of a recombinant vector expressing at least one immunogen from the feline pathogen. The recombinant vector may be a plasmid or a viral vector; for

example the vector can be a poxvirus, an adenovirus, or a herpesvirus. The freeze-dried form is preferred.

The additional non-FCV feline pathogens are preferably selected from the group comprising the feline rhinotracheitis virus or feline herpesvirus (FHV), the feline leukemia virus (FeLV), the feline panleukopenia virus or feline parvovirus (FPV), the feline infectious peritonitis virus (FIPV), the feline immunodeficiency virus (FIV), the rabies virus, and Chlamydia (e.g. *Chlamydophila felis*).

Preferably, the combined immunogenic composition or vaccine combines at least one FCV immunogenic component in addition to non-FCV immunogenic components such as:

- FHV, FPV, FeLV and Chlamydia
- FHV, FPV and FeLV
- FHV, FPV and Rabies
- FHV, FPV and Chlamydia
- FHV, FPV, Chlamydia and Rabies
- FHV and FPV
- FHV and Chlamydia
- FHV

In a preferred embodiment of these various combinations, attenuated live microorganisms are used for FHV, FPV and Chlamydia and a recombinant vector(s) expressing FeLV genes is/are used for FeLV. The recombinant vector may be a canarypox virus (for example vCP97 as described in U.S. Patent No. 5,753,103) that expresses *env* and *gag/pol* FeLV genes. For rabies, a recombinant vector may be used, notably a canarypox virus (for example vCP65 as described in U.S. Patent No. 5,843,456) that expresses G glycoprotein rabies gene.

Another object of the invention is a process of inactivating and stabilizing FCV, comprising reacting FCV with an inactivating agent and a stabilizing aldehyde compound formed of a linear alkyl C1-C5 chain comprising one aldehyde group when the chain is C1 and two terminal aldehyde groups when the chain is C2-C5, and optionally one aldehyde group may be replaced by a ketone or an epoxy group when the chain is the C2-C5 chain. Preferred embodiments for the inactivating agent and the stabilizing aldehyde compound and their conditions of use are as described above.

The process of the invention comprises the culturing of FCV in suitable host cells, the treatment with the inactivating agent and the stabilizing aldehyde compound. The culture and propagation of the FCV virus is preferably carried out on feline cells, more particularly on Crandell-Reese Feline Kidney or CRFK cells (accessible from the American
5 Type Culture Collection under the number CCL-94) with a multiplicity of infection (MOI) of 2 to 0.01 cell culture infectious doses 50% (CCID₅₀) per cell, preferably 0.5 CCID₅₀/cell.

The addition of the stabilizing aldehyde compound can be done before, during or after the inactivation step. Neutralization of the inactivating agent and/or the stabilizing aldehyde compound may be performed as described above.

10 The stabilized inactivated FCV virions may be concentrated and/or recovered from the suspension by conventional concentration techniques, for example by ultrafiltration and then optionally purified by conventional purification means, for example size exclusion chromatography, ultracentrifugation on a sucrose gradient, ultracentrifugation on a cesium chloride gradient, or selective precipitation for example in the presence of polyethylene
15 glycol (PEG).

In one embodiment, the immunogenic composition or vaccine comprises freeze-dried stabilized and inactivated FCV and a freeze-drying excipient or vehicle, which can include amino acids, e.g., glutamic acids, or carbohydrates, e.g, lactose, and mixtures thereof, e.g, SPGA (sucrose/phosphate/glutamate/albumin; see also European Patent
20 Application Serial No 0.496.135). Inactivated and stabilized FCV may be stored long-term at about 5°C, or alternatively, frozen or freeze-dried (or lyophilized) according to techniques known to the skilled artisan.

Therefore, to produce the immunogenic FCV compositions of the present invention, the FCV is grown in cell culture on a suitable feline cell line, i.e., CRFK cells, to titers
25 sufficient for producing a viral suspension in sufficient amounts to produce an immunogenic composition. The FCV is harvested according to methods well known in the art. The calicivirus is then concentrated, frozen, and stored at -70°C or freeze-dried and stored at 4°C.

Still another object of the invention is a process of producing an immunogenic
30 composition or vaccine comprising providing inactivated and stabilized FCV in a sufficient amount to induce an immune response, and either freeze-drying said FCV (and possibly adding a freeze-drying stabilizer) or in liquid form by mixing said FCV with a veterinarily acceptable excipient or vehicle. Suitable excipients are, for example, water, isotonic

solutions, saline such as, but not limited to, NaCl and phosphate buffered saline (PBS), dextrose, mannitol, sorbitol, lactose, glycerol, ethanol, or the like, and combinations thereof. In addition, if desired, the vaccine may contain minor amounts of auxiliary substances such as, but not limited to, wetting or emulsifying agents, and pH buffering agents.

5 The immunogenic compositions and the vaccines according to the invention can comprise one or more adjuvants, but need not. Preferably, the compositions of the invention comprise an inactivated and stabilized FCV that is immunogenic even in the absence of adjuvant. If desired, however, an acceptable adjuvant may be included in the compositions of the invention. The acceptable adjuvant is a hydrosoluble adjuvant. Such
10 acceptable adjuvants may be polymers of acrylic or methacrylic acid, polymers of maleic anhydride and of an alkenyl derivative, immunostimulatory sequences (ISS), in particular oligodeoxyribonucleotide sequences having one or more non-methylated CpG motifs (Klinman D.M. *et al.*, (1996) Proc. Natl. Acad. Sci. USA 93: 2879-2883; WO-A1-98/16247), an oil-in-water emulsion, in particular the SPT emulsion described on
15 page 147 of "Vaccine Design, The Subunit and Adjuvant Approach" edited by M. Powell, M. Newman, Plenum Press 1995, and the MF59 emulsion described on page 183 of the same work, cationic lipids containing a quaternary ammonium salt, cytokines, or combinations or mixtures thereof.

 Still another object of the invention is a method of immunization of an animal of the
20 Felidae family, preferably cats, including newborns, kittens, males, females, and pregnant females, against FCV disease, the method comprising administering a non-adjuvanted inactivated and stabilized FCV immunogenic composition or vaccine according to the invention.

 A further object of the invention is a method of immunization of an animal of the
25 Felidae family, preferably cats, including newborns, kittens, males, females, and pregnant females against at least two feline diseases including FCV disease, the method comprising administering a non-adjuvanted combined vaccine comprising inactivated and stabilized FCV according to the invention, and at least one non-FCV immunogen from another feline pathogen or recombinant vector that expresses at least one non-FCV immunogen from
30 another feline pathogen.

 Different routes may carry out the administration of the immunogenic compositions or vaccines according to the invention. These include, but are not limited to, the parenteral route, oronasal, intramuscular, intradermal, subcutaneous, and mucosal (e.g. oral). The

preferred routes of administration include the subcutaneous or the intramuscular injection route. The vaccine or immunogenic composition can be administered by any means that include, but are not limited to, syringes, needleless injection devices. Needle-free injectors may be used for transdermal delivery (intra-dermal and subcutaneous and possibly intramuscular delivery). Using a needleless injection system, the dose volumes are determined by the volume necessary to deliver the FCV immunogenic composition and may be between 0.1 ml and 1 ml.

Using a syringe, the dose volumes of the vaccines and immunogenic compositions are generally between 0.2 and 2.0 ml, preferably about 1.0 ml. Cats may be vaccinated from about 6 weeks of age. Two or more administrations may be performed, for example 3-5 weeks apart. Preferably a boost administration may be performed, for example annually. Alternatively cats can be primed with only one injection.

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

EXAMPLES

Example 1: Inactivation of FCV by Formaldehyde

CRFK cells (Crandell-Reese Feline Kidney cells, accessible from the American Type Culture Collection under CCL-94) were cultured at 37°C in 2-liter roller flasks (850 cm²) with modified Eagle's medium (MEM, Gibco BRL) supplemented with 2.5% of lactalbumin hydrolysate and 5% fetal calf serum. Three hundred milliliters of a cellular suspension in MEM medium, containing about 100,000 cells/ml, were added per roller flask. After 3 days, the cell layer became confluent. The cell culture medium was then replaced with serum-free MEM and strain 431 FCV virus was added at a multiplicity of infection (MOI) of 0.5 CCID₅₀/cell. The viral culture was maintained at 37°C for 24 to 48 hours until a cytopathic effect was obtained for the whole cellular layer. The viral suspension was harvested and then clarified on a filter having a porosity of 1.5 µm and stored at 5°C. The FCV virus titer at harvest was 8.5 +/-0.3 log₁₀ CCID₅₀/ml.

The viral suspension was inactivated with ethyleneimine at the concentration of 8 mM at 22°C for 18 hours. The ethyleneimine was prepared by dissolving 36 g of sodium hydroxide pellets in 257.5 ml of distilled water and adding 87.5 g of bromoethylamine (BEA), corresponding approximately to a 1.2 M solution of ethyleneimine. At the end of inactivation, part of the inactivated viral suspension was stabilized by addition of

formaldehyde at a final concentration of 0.5 g/l and at 5°C (+/- 3°C) during 24 hours. Part of the inactivated viral suspension was kept unstabilized as a control suspension.

A portion of the inactivated and stabilized viral suspension and a portion of the control suspension were subjected to selective precipitation in the presence of polyethylene glycol (PEG). PEG 6000 was added to the suspensions at a concentration of 6%, and agitated at 5°C (+/- 3°C) for 3 hours. Suspensions were then centrifuged at about 1330 g during 90 minutes. The supernatants, containing the soluble p66 protein, and the precipitates, containing the virions, were separated and recovered. The precipitates were dissolved in sterile phosphate buffer saline (PBS) without calcium and without magnesium.

Two to three days after the end of the inactivation step, FCV p66 proteins were quantified by ELISA titration in the inactivated and stabilized viral suspension, in the control suspension, in the supernatants and in the precipitates in solution. Coating anti-FCV polyclonal antibodies on a titration plate, adding different dilutions of the inactivated and stabilized viral suspension, the control suspension, the supernatants and the precipitate solution, performed ELISA titration. The titration plate was kept at 37°C for 3 hours, followed by washing the titration plate with a washing buffer, and subsequently adding a monoclonal antibody specific for FCV p66 capsid protein coupled to a peroxidase. The titration plate was further incubated at 37°C during 1 hour, after which the plate was washed with the washing buffer. To the washed plate, 100 µl of TMB solution (5,5'-tetramethylbenzidine) per well was added at 20°C, and kept in the dark at 20°C for 30 minutes. The color development was blocked by adding 50 µl of 2M sulfuric acid per well. The ELISA titers were optically measured and expressed as log₁₀ OD₅₀ (optical density 50%), which correspond to the decimal logarithm of the dilution, giving 50% of the maximum optical density. Standard deviation of the ELISA titration is 0.07.

Table 1: Degradation of FCV virions after inactivation

	Inactivation without stabilization	Inactivation and stabilization
Total p66 protein in the viral suspension not subjected to PEG precipitation	2.81	2.36
P66 protein in the supernatant (soluble p66)	2.55	2.18
P66 protein in the precipitate (p66 on virion)	1.95	2.62

These results demonstrate the degradation of FCV virions after inactivation in absence of stabilization and the stabilization effect of formaldehyde.

Example 2: Stabilizing Effect of Formaldehyde on FCV under Various Conditions

5 The FCV 431 strain was cultured essentially as described in Example 1.

Three methods of inactivation were tested:

- 1) ethyleneimine at the concentration of about 4 mM at 20°C for 24 hours,
- 2) ethyleneimine at the concentration of about 8 mM at 20°C for 24 hours,
- 3) ethyleneimine at the concentration of about 8 mM at 5°C for 24 hours.

10 The viral suspension was stabilized by formaldehyde at various final concentrations of 0.1 g/l - 0.5 g/l and at 5°C (+/- 3°C) during 5 days. A control suspension did not contain any formaldehyde.

The FCV p66 proteins were quantified as described in Example 1 before and after selective PEG precipitation, by ELISA titration. The ELISA titers are expressed as log10

15 OD₅₀.

Table 2: ELISA Titers of FCV p66 proteins

Formaldehyde 5 days, 5°C	Ethyleneimine								
	4 mM, 20°C, 24h			8 mM, 20°C, 24h			8 mM, 5°C, 24h		
	Total of protein	Soluble p66	p66 on virion	Total of protein	Soluble p66	p66 on virion	Total of protein	Soluble p66	p66 on virion
0.5 g/l	2.15	1.53	1.56	1.96	1.37	1.09	2.11	1.42	1.38
0.1 g/l	2.38	1.88	1.56	2.24	1.87	0.98	2.27	1.72	1.35
0 g/l	2.41	1.86	1.34	2.14	1.85	0.82	2.3	1.76	1.14

These results demonstrated the stabilizing effect of 0.1 g/l and 0.5 g/l of formaldehyde solution in relation to various inactivation conditions.

20

Example 3: Immunogenicity of Inactivated FCV virions

FCV 431 strains were cultured, inactivated and stabilized essentially as described in Example 1. This viral suspension was separated by size exclusion chromatography into two fractions containing, respectively, the virion (also named viral p66 fraction) and the soluble p66 protein (also named soluble p66 fraction). After separation, the two fractions were

25 stored at 5°C.

A total of 12 vaccines were prepared, containing 1 ml of the viral p66 fraction diluted or undiluted (1/1, 1/4 and 1/16) and formulated with 1 ml of PBS (phosphate-buffered saline; without calcium and without magnesium); 1 ml of the viral p66 fraction diluted or undiluted (1/1, 1/4 and 1/16) and formulated with 1 ml of an oil-in-water emulsion (paraffin oil, fatty alcohol ethers and polyols, polyoxyethylene fatty acids); 1 ml of the soluble p66 fraction diluted or undiluted (1/1, 1/4 and 1/16) and formulated with the PBS; 1 ml of the soluble p66 fraction diluted or undiluted (1/1, 1/4 and 1/16) and formulated with the oil-water-emulsion.

The undiluted vaccines contain approximately the quantity of protein corresponding to 10 ml of crude viral culture. The viral p66 fractions and the soluble p66 fractions were diluted by addition of PBS without calcium and without magnesium.

Twenty-four specific pathogen free (SPF) kittens, each approximately 8-9 weeks old, were randomized into 12 groups and administered subcutaneously twice, 28 days apart, with 2 ml of these vaccines. No effect was observed relating to the injected quantity of p66 protein. The following results are reflective of all cats that were challenged via the oronasal route with FCV 431 virulent strain on day 46 (0.25 ml per nostril and 0.5 ml orally, $10^{5.5}$ CCID₅₀/ml).

Clinical signs were observed during the two weeks post-challenge. The scoring used for the calculation of the clinical score is as follow:

Table 3: Clinical Scores of Vaccinated Felines

Parameters	Observation	Score
Rectal temperature	$T^{\circ} < 39.5^{\circ}\text{C}$	0
	$39.5^{\circ}\text{C} \leq T^{\circ} < 40^{\circ}\text{C}$	1
	$T^{\circ} \geq 40^{\circ}\text{C}$	2
General body condition	Normal	0
	Depression	1
Oronasal ulceration	Absence	0
	Diameter < 5 mm	1
	Diameter from 5 to 10 mm	2
	Diameter > 10 mm	3
Rhinitis	Serous nasal discharge	1
	Muco-purulent nasal discharge	2

Conjunctivitis	Serous discharge	1
	Muco-purulent discharge	2
Gingivitis	Present	1
Limping	Present	1

The total clinical score is the addition of all the clinical signs observed in a cat during the two weeks post-challenge. Means of the total clinical score per type of vaccines are indicated in the following table and in Figure 1.

5 Table 4: Mean Total Clinical Score Per Type of Vaccine

	Viral p66 fraction	Soluble p66 fraction
PBS	17.17	29.33
Emulsion	16.17	20.83

The maximum clinical score is the highest clinical score obtained for an observation on a cat during the two weeks post-challenge. Means of the maximum clinical score per type of vaccines are indicated in the following table and in Figure 2.

10 Table 5: Mean Maximum Clinical Score Per Type of Vaccine

	Viral p66 fraction	Soluble p66 fraction
PBS	2.33	4.67
Emulsion	2.83	2.83

There was a significant difference between means of the maximum clinical score obtained for viral p66 fraction/PBS and soluble p66 fraction/PBS groups (P-value, $p=0.0495$).

15 These results demonstrate that the inactivated virions maintain immunogenicity in absence of adjuvant. In the contrary, soluble p66 proteins induce a good immunogenic response only in presence of adjuvant.

Example 4: Vaccination of Cats with Inactivated FCV

20 FCV 431 was cultured, inactivated with ethylenimine and stabilized by action of formaldehyde essentially as described in Example 1. The same procedure was applied for the FCV G1 strain.

A combined vaccine (vaccine A) comprised 5.60 log₁₀ CCID₅₀ per dose of attenuated feline rhinotracheitis virus (FHV-1), 4.17 log₁₀ CCID₅₀ per dose of attenuated feline panleucopenia virus (FPV), 8.29 log₁₀ CCID₅₀ per dose of canarypox vCP97 recombinant vector expressing *env* and *gag/pol* FeLV genes (see US-A-5.753.103), 4.8 log₁₀ ELD₅₀ per dose of attenuated Chlamydia, 8.7 log₁₀ CCID₅₀ per dose of inactivated and stabilized FCV 431 (equivalent titer of FCV before inactivation), 8.7 log₁₀ CCID₅₀ per dose of inactivated and stabilized FCV G1 (equivalent titer of FCV before inactivation), and physiological water.

Eighteen specific pathogen free kittens between 8 and 9 weeks old were randomized in 3 groups (6 kittens per group). The kittens of the group A were vaccinated with one dose of the vaccine A. The kittens of the group B were vaccinated with a mixture of a commercial vaccine containing in a freeze-drying form, a modified live FCV F9 strain, a modified live FHV-1 and a modified live FPV, and of a commercial vaccine containing an inactivated FeLV and Carbopol® adjuvant, this vaccine acting as diluent for the freeze-dried commercial vaccine. The kittens of the group C remained not vaccinated as control. The vaccine was administered twice, 28 days apart, by subcutaneous route. Four weeks after the last vaccination, all cats were challenged via the oronasal route with FCV 255 virulent heterologous strain (Scott FW. Am. J. Vet. Res. 1977. 38(2). 229-34) (0.25 ml per nostril and 0.5 ml orally, 10^{8.2} CCID₅₀/ml).

Anti-FCV255 neutralizing antibodies, animal weights, rectal temperatures, general conditions, general and local symptoms and viral excretions were observed during the two weeks post-challenge. The calicivirus antibody titers (expressed as log₁₀) are presented in the following table and in Figure 3.

Table 6: Antibody Titers According to Group

	D0	D28	D56	D70
Group A	0.20	0.20	1.13	2.23
Group B	0.20	0.62	1.28	2.43
Group C	0.20	0.20	0.20	2.83

On Day 0, antibody titers were negative in all groups.

After one injection of the vaccine, none of the vaccinated cats seroconverted except in group B. After the second injection, all cats had neutralizing antibody titers. Mean

antibody titers at the time of challenge (D56) were not different between vaccinated groups (Tukey test) but were significantly higher than in the control group (ANOVA, $p=0.0002$).

The scoring used for the calculation of the global score is as follow:

Table 7: Global Clinical Score of Vaccinated Cats

Parameters	Observation	Score
Rectal temperature	$T^{\circ} \geq 39.5^{\circ}\text{C}$	1
	$T^{\circ} \leq 37^{\circ}\text{C}$	2
General body condition*	Depression	2
	Death	10
Oronasal ulceration*	Small and few in number	1
	Large and numerous	3
Nasal discharge*	Slight	1
	Copious	2
Ocular discharge*	Present	1
Weight	Weight loss	2

5

*The addition of the scores of the general body condition, oronasal ulceration, nasal discharge and ocular discharge represents the score of clinical symptoms as shown in Figure 4.

The clinical score results are presented in the following table and in Figure 4.

10

Table 8: Clinical Scores of Vaccinated Cats

	Group A	Group B	Group C
Rectal temperature	2	1	3
Weight loss	18	20	22
Clinical symptoms	4	43	116

All control cats, except one, exhibited typical FCV infection clinical symptoms. A pairwise comparison with the Tukey test showed that the group A was the only vaccinated group to be significantly different from the control group.

15

Pharyngeal swabs were collected and tested for viral excretion. The FCV excretion results (expressed as $\log_{10}$ CCID₅₀/ml) are presented in the following table and in Figure 5.

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Table 9: Excretion Levels of FCV in Vaccinated Cats

	D56	D58	D60	D62	D64	D67	D70
Group A	1.20	2.20	2.28	1.62	1.70	1.45	1.70
Group B	1.20	1.95	1.37	1.45	1.53	1.28	1.37
Group C	1.28	3.12	3.20	3.45	2.87	2.20	1.62

After challenge, viral excretion was observed in all groups but was reduced in vaccinated groups compared to the control group (ANOVA, $p < 0.00001$). There was no
5 difference between vaccinated groups (Tukey test).

Both vaccines protected cats against a heterologous FCV 255 challenge by strongly reducing clinical symptoms and viral excretion. The level of protection of the vaccines of the invention was at least as good as that of the commercial modified live F9 vaccine. This demonstrates that an effective vaccination against FCV may be attained using an inactivated
10 and stabilized FCV vaccine in the absence of adjuvant and that the level of protection is at least as good as that obtained with commercial live vaccines.

The in vivo compatibility between inactivated and stabilized FCV431/G1 and the other vaccine components (feline rhinotracheitis virus, feline infectious panleukopenia virus, feline leukemia virus and Chlamydia) has also been demonstrated.

15 Having thus described in detail preferred embodiments of the present invention, it is to be understood that the invention defined by the appended claims is not to be limited by particular details set forth in the above description as many apparent variations thereof are possible without departing from the scope thereof.

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CLAIMS:

1. An inactivated, stabilized, non-adjuvanted immunogenic composition against feline calicivirus (FCV), comprising an FCV inactivated by one or more inactivating agents and stabilized by an aldehyde compound, wherein the aldehyde compound comprises a linear C1-C5 alkyl chain, and wherein the immunogenic composition is in admixture with an acceptable excipient or vehicle and wherein the inactivating agents are selected from the group consisting of ethyleneimine, acetyleneimine, propyleneimine, and β -propiolactone.
2. The composition of claim 1, wherein the excipient or vehicle is veterinarily acceptable.
3. The composition of claim 1, wherein the composition is freeze-dried and is in admixture with a freeze-drying excipient or vehicle.
4. The composition of any one of claims 1 to 3, wherein the inactivating agent is β -propiolactone.
5. The composition of any one of claims 1 to 3, wherein the inactivating agent is ethyleneimine and wherein the ethyleneimine is present from about 0.5 mM to about 20 mM.
6. The composition of any one of claims 1 to 3, wherein the inactivating agent is ethyleneimine and wherein the ethyleneimine is present from about 1 mM to about 10 mM.
7. The composition of any one of claims 1 to 6, wherein the aldehyde compound comprises a linear C1 alkyl chain and wherein the aldehyde compound comprises one aldehyde group.
8. The composition of any one of claims 1 to 6, wherein the aldehyde compound comprises a linear C2-C5 alkyl chain and wherein the aldehyde compound comprises two aldehyde groups.

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9. The composition of claim 8, wherein one of the two aldehyde groups is replaced by a ketone or an epoxy group.

10. The composition of any one of claims 1 to 6, wherein the aldehyde compound is selected from the group consisting of formaldehyde, glycidaldehyde,
5 glutaraldehyde, glyoxal, and methylglyoxal.

11. The composition of claim 10, wherein the aldehyde compound is formaldehyde and wherein the formaldehyde is present from about 0.05 g/l to about 0.5 g/l.

12. The composition of claim 10, wherein the aldehyde compound is
10 formaldehyde and wherein the formaldehyde is present from about 0.1 g/l to about 0.5 g/l.

13. The composition of any one of claims 1 to 12, further comprising a neutralizing compound, wherein the neutralizing compound comprises thiosulfate and cysteine.

15 14. The composition of any one of claims 1 to 13, further comprising at least one additional FCV strain, wherein at least one or both of the FCV strains is inactivated and stabilized.

15. The composition of claim 14, wherein the at least one additional FCV strain is selected from the group consisting of FCV US 100869 (FCV PTA 5930), FCV
20 F9, FCV 255, FCV 2280, FCV 431, FCV G1, FCV LLK, FCV KCD, FCV CFI, and FCV M8.

16. The composition of any one of claims 1 to 15, further comprising at least one non-FCV immunogen from a feline pathogen.

17. The composition of claim 16, wherein the feline pathogen is selected
25 from the group consisting of feline herpesvirus (FHV), feline leukemia virus (FeLV), feline panleukopenia virus (FPV), feline infectious peritonitis virus (FIPV), feline immunodeficiency virus (FIV), rabies virus, and feline Chlamydia.

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18. The composition of claim 16, wherein the at least one non-FCV immunogen from a feline pathogen comprises a live attenuated microorganism or a recombinant vector that expresses at least one immunogen from a feline pathogen.

19. A process for inactivating and stabilizing feline calicivirus (FCV),
5 comprising the steps of reacting FCV with an inactivating agent and an aldehyde compound, wherein the aldehyde compound comprises a linear C1-C5 alkyl chain, and wherein the inactivating agent is selected from the group consisting of ethyleneimine, acetyleneimine, propyleneimine, and β -propiolactone, and recovering the inactivated and stabilized FCV.

10 20. The process of claim 19, wherein the inactivating agent is β -propiolactone.

21. The process of claim 19, wherein the inactivating agent is ethyleneimine and wherein the ethyleneimine is present from about 0.5 mM to about 20 mM.

15 22. The process of claim 19, wherein the inactivating agent is ethyleneimine and wherein the ethyleneimine is present from about 1 mM to about 10 mM.

23. The process of any one of claims 19 to 22, wherein the aldehyde compound comprises a linear C1 alkyl chain and wherein the aldehyde compound comprises one aldehyde group.

20 24. The process of any one of claims 19 to 22, wherein the aldehyde compound comprises a linear C2-C5 alkyl chain and wherein the aldehyde compound comprises two aldehyde groups.

25. The process of claim 24, wherein one of the two aldehyde groups is replaced by a ketone or an epoxy group.

25 26. The process of any one of claims 19 to 22, wherein the aldehyde compound is selected from the group consisting of formaldehyde, glyceraldehyde, glutaraldehyde, glyoxal, and methylglyoxal.

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27. The process of claim 26, wherein the aldehyde compound is formaldehyde and wherein the formaldehyde is present from about 0.05 g/l to about 0.8 g/l.

28. The process of claim 26, wherein the aldehyde compound is formaldehyde and wherein the formaldehyde is present from about 0.1 g/l to about 0.5 g/l.

29. The process of any one of claims 19 to 28, further comprising the step of reacting the inactivated and stabilized FCV with a neutralizing compound, wherein the neutralizing compound comprises thiosulfate and cysteine.

30. The process of any one of claims 19 to 28, wherein the inactivated and stabilized FCV is recovered by size exclusion chromatography, ultracentrifugation, and selective precipitation.

31. The process of any one of claims 19 to 30, further comprising the step of freeze-drying the inactivated and stabilized FCV in a freeze-drying excipient.

32. A process for producing an inactivated, non-adjuvanted immunogenic composition, comprising mixing the inactivated and stabilized feline calicivirus (FCV) as defined in claim 1 in an amount sufficient to induce an immune response to FCV with a veterinarily acceptable excipient or vehicle.

33. A process for producing an inactivated, non-adjuvanted immunogenic composition for long-term storage, comprising mixing the inactivated and stabilized feline calicivirus (FCV) as defined in claim 1 in an amount sufficient to induce an immune response to FCV with a freeze-drying excipient and freezing the composition.

34. The inactivated, stabilized, non-adjuvanted immunogenic composition of claim 1 for use in inducing an immune response in a Felidae against FCV.

35. The inactivated, stabilized, non-adjuvanted immunogenic composition of claim 17 for use in inducing an immune response in a Felidae against FCV.

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36. A combination comprising the inactivated, stabilized, non-adjuvanted immunogenic composition of claim 1 and at least one non-FCV immunogen from a feline pathogen for use in inducing an immune response in a Felidae against FCV and the at least one non-FCV immunogen from a feline pathogen.

5 37. The combination according to claim 36, wherein the feline pathogen is selected from the group consisting of feline herpesvirus (FHV), feline leukemia virus (FeLV), feline panleukopenia virus (FPV), feline infectious peritonitis virus (FIPV), feline immunodeficiency virus (FIV), rabies virus, and feline Chlamydia.

38. The combination according to claim 36, wherein the at least one non-FCV immunogen from a feline pathogen comprises a live attenuated microorganism or a recombinant vector that expresses at least one immunogen from a feline pathogen.

39. Use of the inactivated, stabilized, non-adjuvanted immunogenic composition of any one of claims 1 to 18 for inducing an immune response in a Felidae against FCV.

40. Use of a combination comprising the inactivated, stabilized, non-adjuvanted immunogenic composition of claim 1 and at least one non-FCV immunogen from a feline pathogen for inducing an immune response in a Felidae against FCV and the at least one non-FCV immunogen from a feline pathogen.

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Means of the total clinical scores per type of vaccines

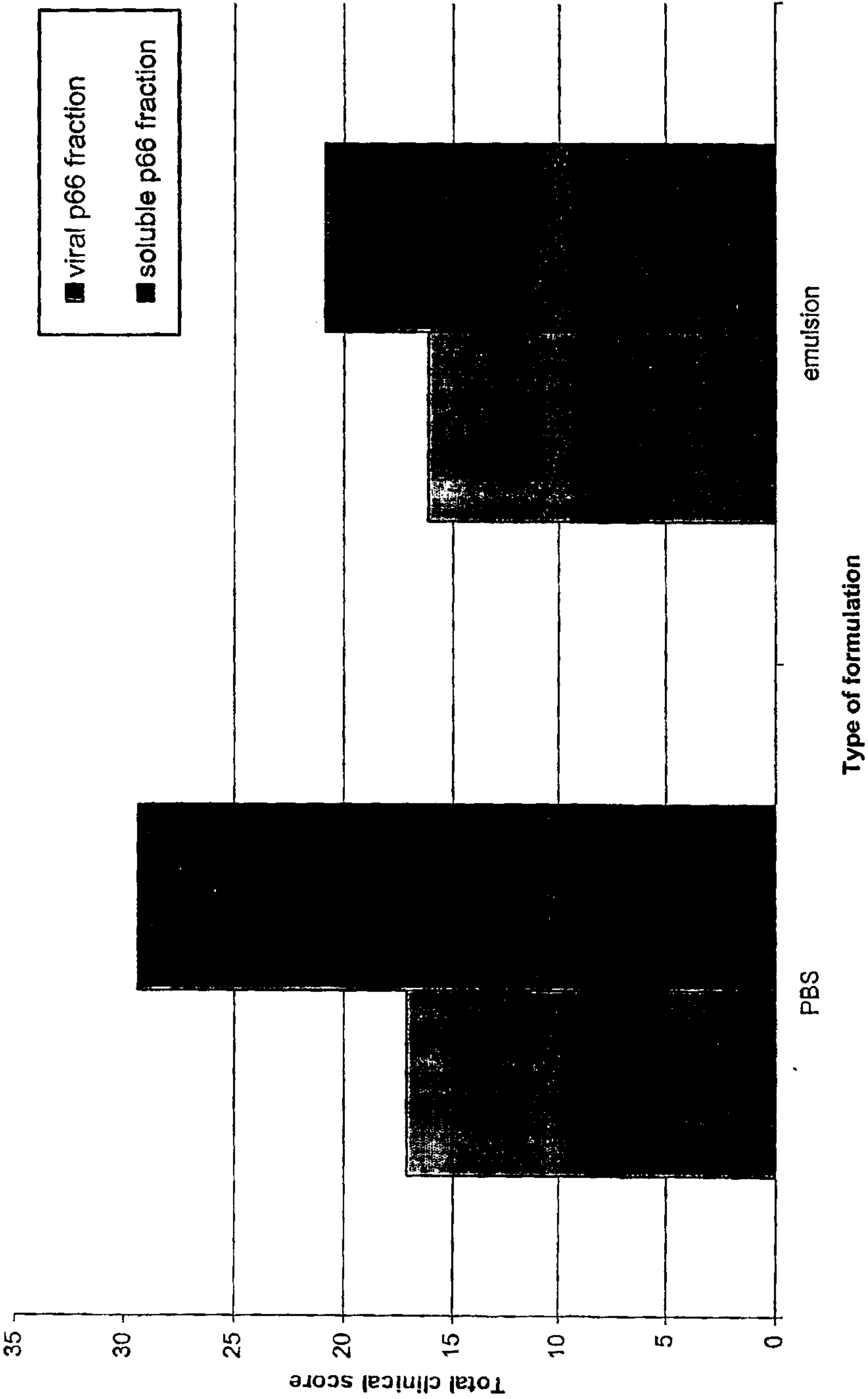


FIG. 1

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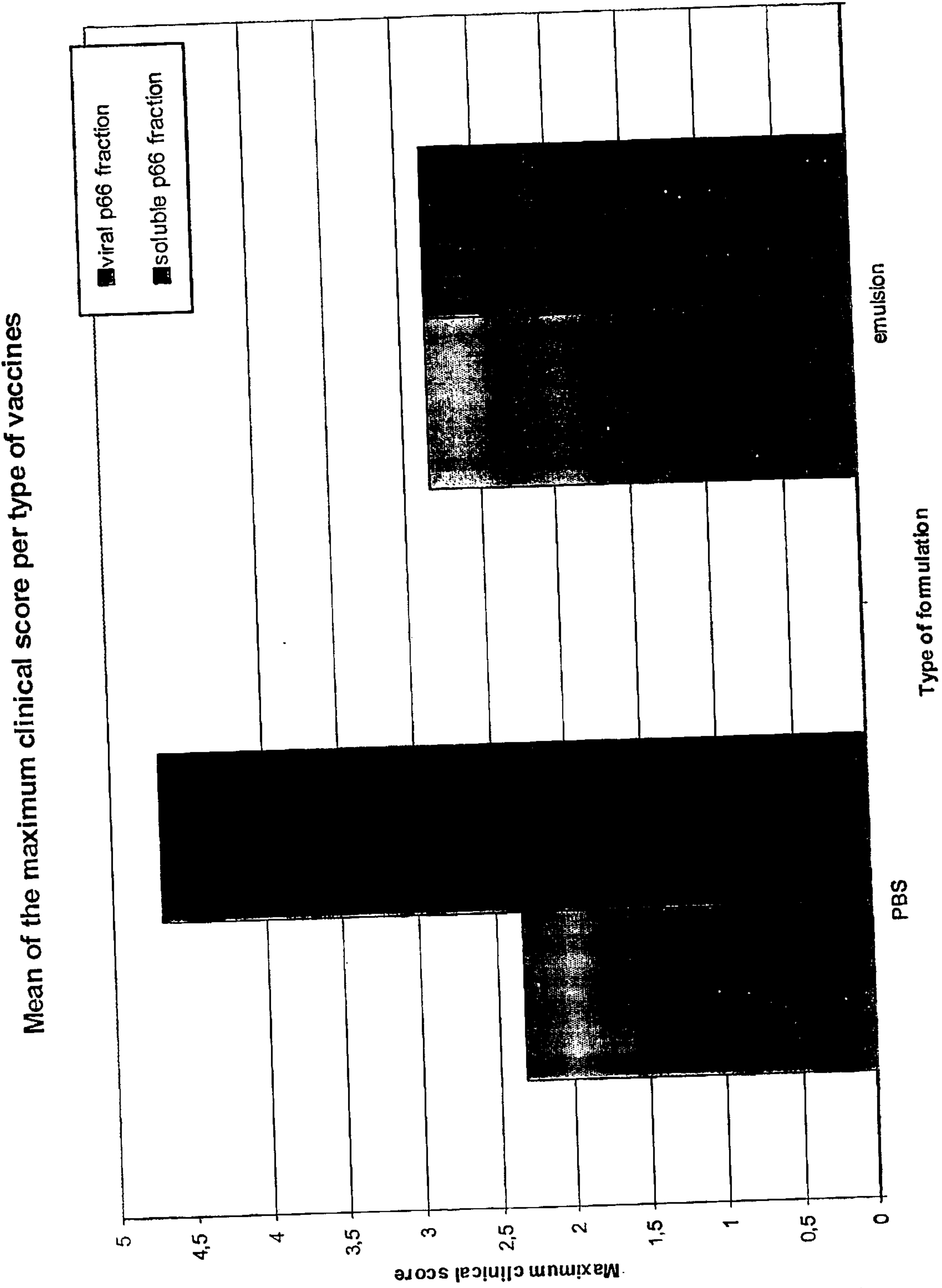


FIG. 2

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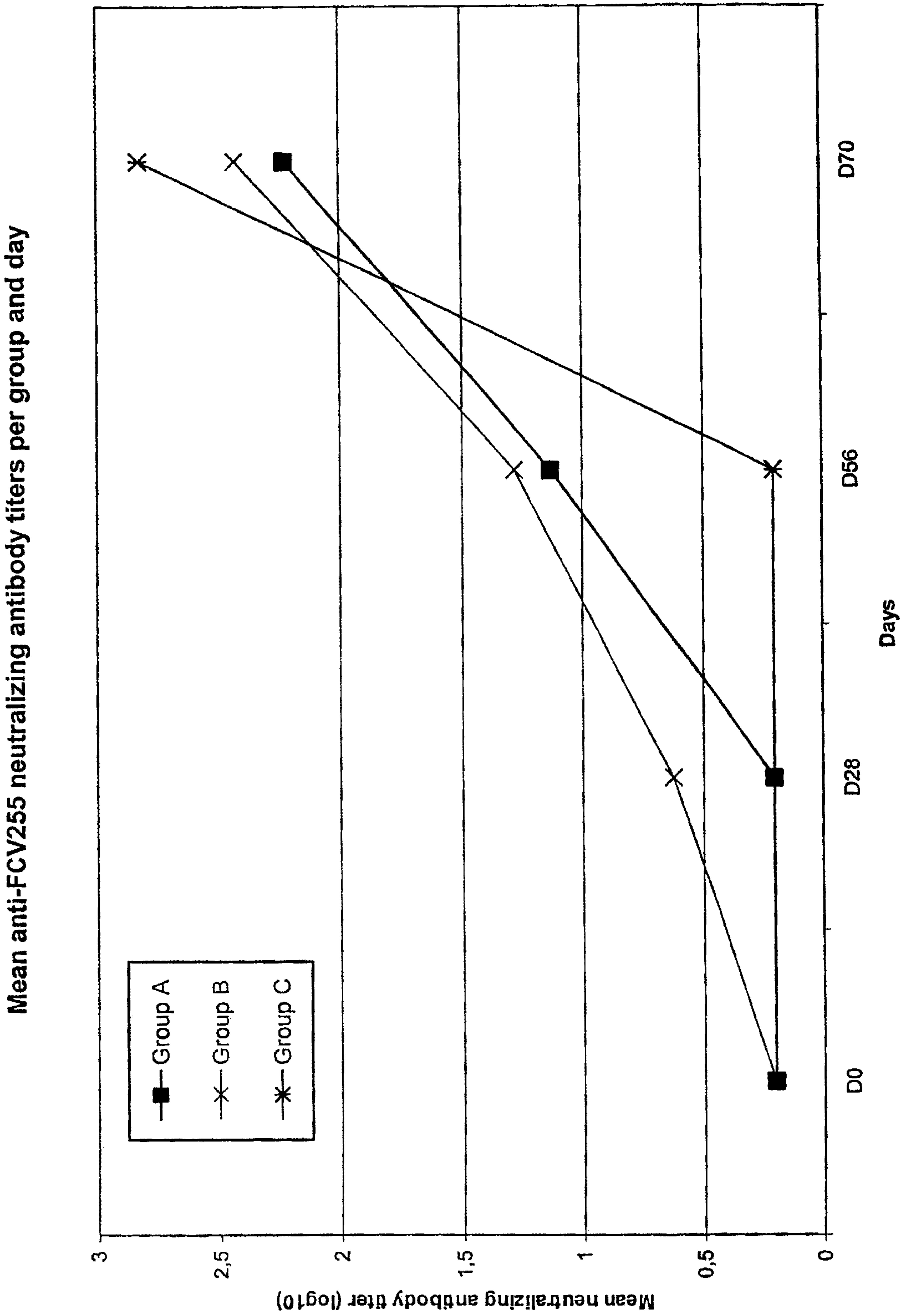
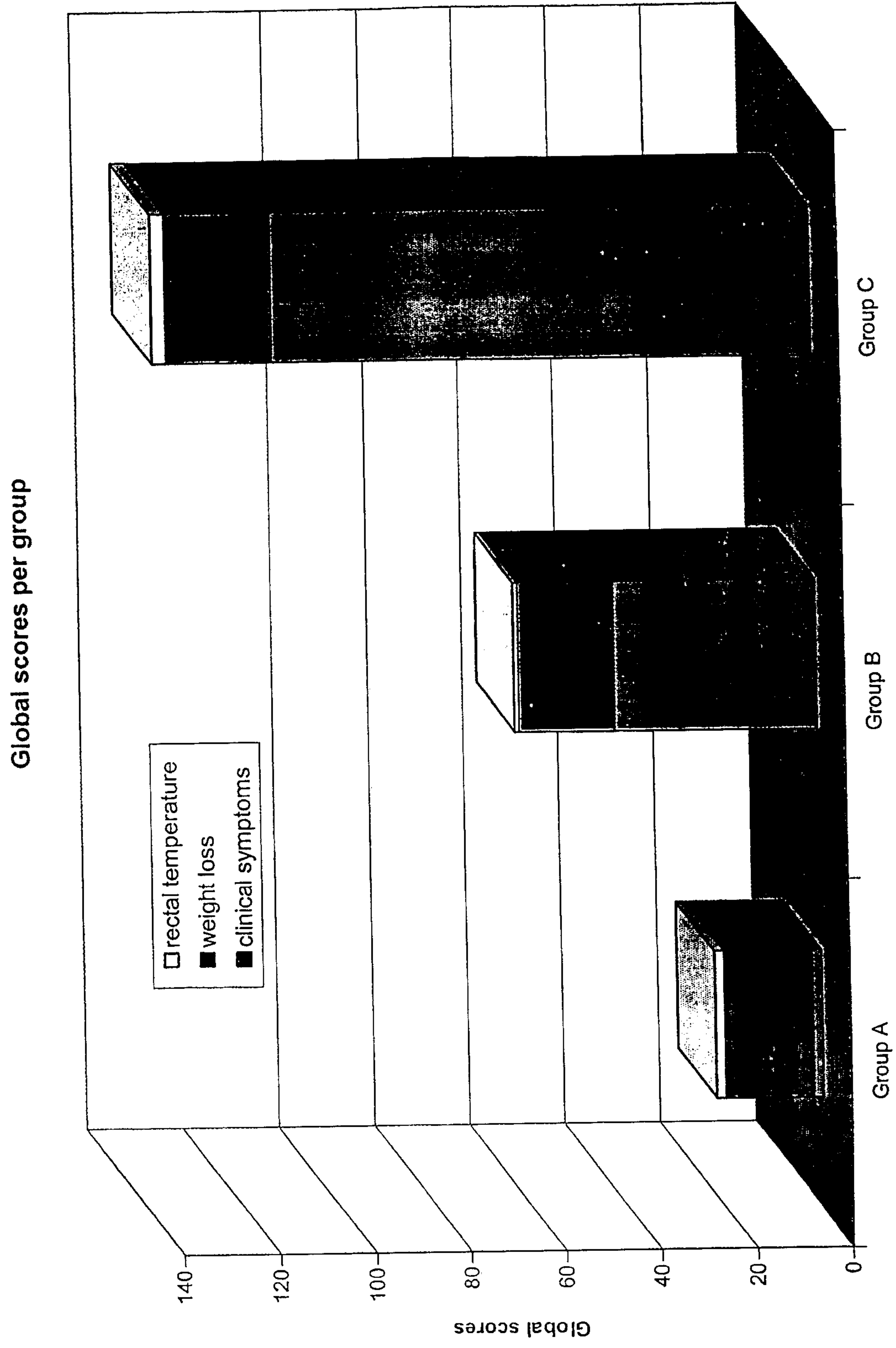


FIG. 3

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**FIG. 4**

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Mean FCV excretion (log10 CCID50/ml) after challenge per group and day

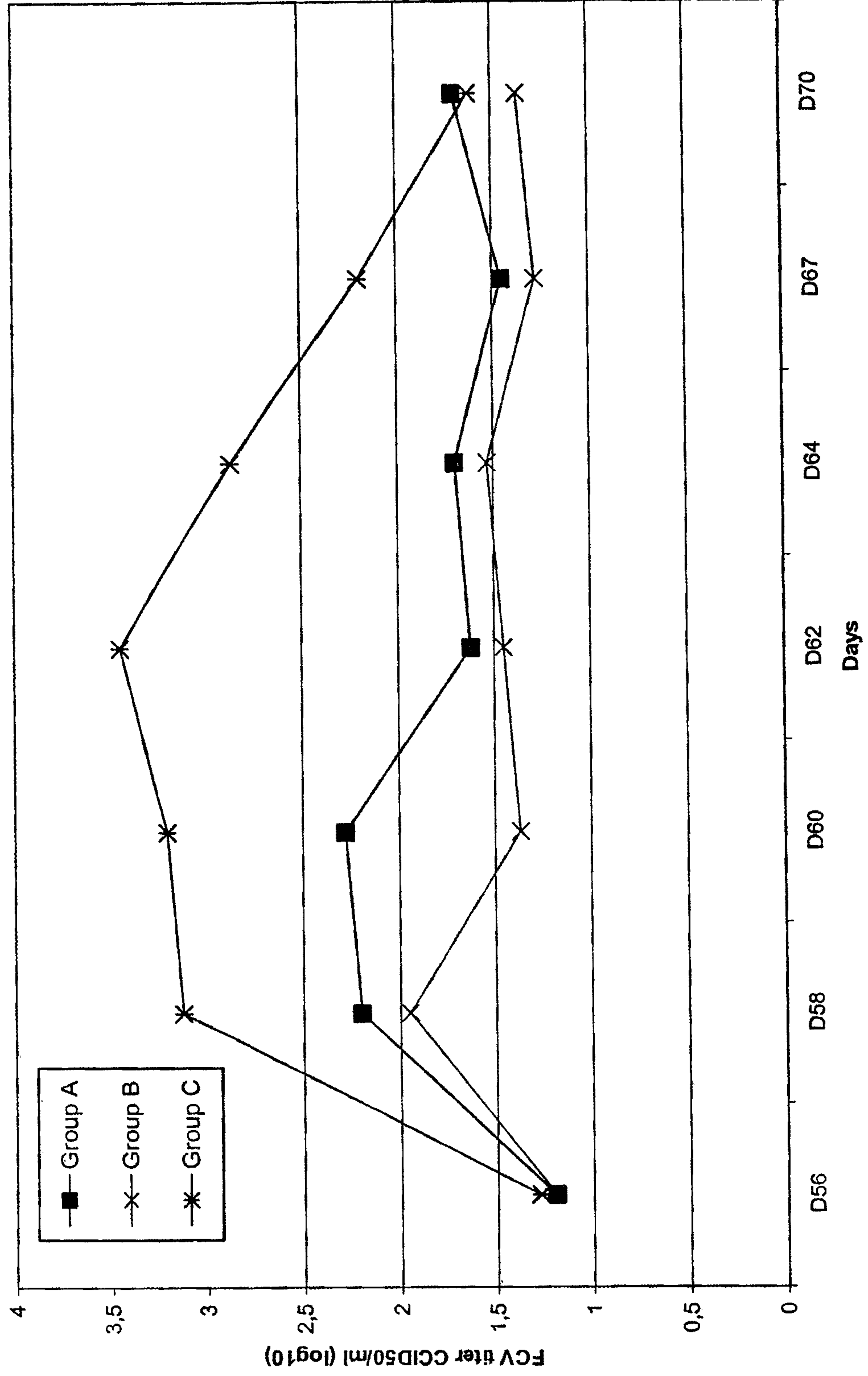


FIG. 5

Means of the total clinical scores per type of vaccines

