CHIMERIC RECOMBINANT ANTIGENS OF *TOXOPLASMA GONDII*

FIELD OF THE INVENTION

The invention described herein relates to the technical field of the preparation of diagnostic means not applied directly to the animal or human body. The invention also furnishes compounds, methods for their preparation, methods for their use and compositions containing them, which are suitable for industrial application in the pharmaceutical and diagnostic field, particularly for the detection and diagnosis of *Toxoplasma gondii* infections, as well as for the treatment and prevention of said infections.

BACKGROUND OF THE INVENTION

Early diagnosis is a priority and highly desirable objective in all fields of medicament, particularly because it allows an appreciable improvement in the patient's life and a concomitant saving on the part of health care systems or on the part of the actual patients. In the particular case of the invention described herein, early diagnosis is that of potential or existing *Toxoplasma gondii* infection in pregnant women, with particular concern for the health of the foetus, and in infected subjects, particularly those with impaired immunity.

Toxoplasma gondii is an obligate intracellular parasite that infects all mammalian cells, including those of human subjects (*McCabe and Remington, N. Engl. J. Med. 1988, 318-313-5)*. Morphologically, the parasite exhibits three distinct forms of infection: tachyzoite (asexual), bradyzoite (in tissue cysts, asexual) and sporozoite (in oocysts, sexual reproduction). Transmission typically occurs through ingestion of undercooked meat harbouring tissue cysts or vegetables contaminated with oocysts shed by cats. Human infection is generally asymptomatic and self-limiting in immunocompetent hosts. In contrast, in subjects with impaired immunity (particularly those affected by AIDS), toxoplasmosis is a severe opportunist infection, which may give rise to encephalitis with very serious outcomes (*Luft, B.J., Remington J.S., 1992, Clin.*

Infect. Dis. 15, 211-22). Moreover, contracting primary infection during pregnancy may lead to miscarriages or to severe foetal disease in mammals.

For an extensive overview of the problem of toxoplasmosis the reader is referred to the specific medical literature.

Diagnosis of *T. gondii* infection is established by isolating the micro-organism in the blood or body fluids, identifying the parasite in tissues, detecting specific nucleotide sequences with PCR, or detecting specific anti-*T. gondii* immunoglobulins produced by the host in response to the infection (*Beaman et al., 1995 Principles and Practice of Infectious Diseases 4th Ed., Churchill Livingstone Inc., New York, 2455-75; Remington JS et al. 1995, Infectious Diseases of the Fetus and Newborn Infant, W.B. Saunders, Philadelphia, PA, 140-267*).

Main challenges for clinicians are the diagnosis of primary *T. gondii* infections in pregnant women and the diagnosis of congenital infection in their newborns/infants. In both cases, to implement suitable therapies in good time and to avoid possible damage to the foetus and newborns/infants, it is very important to establish if the parasitic infection has been contracted before or after conception in pregnant women. Moreover, it is essential determining when the vertical transmission from the mother to the foetus occurred. Finally, for the clinical management of newborns/infants there is an urgent need of a sensitive diagnostic method than can discriminate, early in their life, between infected and uninfected subjects, both born to mothers with primary toxoplasmosis in pregnancy.

Seroconversion during gestation and diagnosis of congenital infection in neonates are generally done by attempting to detect the presence of the various classes of anti-*Toxoplasma* immunoglobulins (IgG, IgM, IgA, avidity of IgG), and to compare the immunological profiles of the mother versus her child.

However, the available commercial assays do not provide enough sensitivity and specificity to allow a correct diagnosis of infection in all patients. Therefore the availability of specific, sensitive and innovative diagnostic agents is desirable.

T. gondii antigens have long been known and available, first of all as antigen mixtures obtained in various ways (FR 2,226,468, Mérieux; SU 533376, Veterinary Research Institute; JP 54044016, Nihon Toketsu Kanso), then as subsequent isolations of pure antigens (EP 0 082 745, Mérieux; EP 0 301 961, INSERM, Pasteur; WO 89/5658, Transgene) and their characterization both as proteins, and of their respective genes (WO 89/08700, U. Leland, Dartmouth Coll.; US 4,877,726, Res. Inst. Palo Alto; WO 89/12683, INSERM, Pasteur; EP 0 391 319, Mochida Pharm.; IT 1,196,817, CNR; EP 0 431 541, Behringwerke; WO 92/01067, CNRS; WO 92/02624, U. Flinders; WO 92/11366, Innogenetics, Smithkline Beecham; US 5,215,917, Res. Inst. Palo Alto; WO 92/25689, FR 2702491, INSERM, Pasteur; WO 96/02654, bioMeriéux, Transgene; EP 0 710 724 Akzo; EP 0 724 016, bioMeriéux; EP 0 751 147, Behringwerke; US 5,633,139, Res. Inst. Palo Alto; WO 97/27300, Innogenetics; US 5,665,542, US 5,686,575, Res. Inst. Palo Alto; WO 99/32633, Heska; JP 11225783, Yano; WO 99/61906, Abbott; WO 99/66043, Smithkline Beecham; JP 2000300278, Yano; WO 00/164243, Virsol), and finally, the isolation and characterization of the antigenic regions of *Toxoplasma* gene products (WO 03/080839, Kenton S.r.l.)

Numerous studies have found various different antigenic proteins of *T. gondii* and the gene sequences of these have also been determined.

Among the most interesting proteins both for diagnostic and therapeutic purposes, in the form of vaccines, we should mention: the microneme proteins (WO 03/080839, Kenton S.r.l. ; *Beghetto et al., The Journal of Infectious Diseases, 2005, 191:637-645; Beghetto et al., International Journal for Parasitology, 2003, 33:163-173*); the surface antigens SAG1 (or P30) (WO

89/08700, Stanford University; WO 89/12683 Pasteur, INSERM; WO 94/17813, WO 96/02654, Transgene, bioMeriéux; EP 0 724 016, WO 99/61906, US 5,962,654, *Haming et al., Clinical and Diagnostic Laboratory Immunology, May 1996, 355-357*) and SAG2 (or P22) (*Parmley et al., 1992, J. Clin. Microbiol. 30, 1127-33*); the dense granule proteins GRA1 (or P24) (EP 0 301 961, Pasteur, INSERM; WO 89/05658, Transgene, *Cesbron-Delauw, et al., 1989 P.N.A.S. USA 86, 7537-41*), GRA2 (or P28) (WO 93/25689, INSERM, Pasteur; US 5,633,139, US 5,665,542, US 5,686,575, Res. Inst. Palo Alto; *Prince et al., Mol. Biochem. Parasitol., 34 3-14*), GRA4 (*Mevelec et al., Mol. Biochem. Parasitol. 56, 227-38*), GRA6 (or P32) (FR 2,702,491, INSERM, Pasteur; *Lecordier al., Mol. Biochem. Parasitol. 70, 85-94*), GRA7 (WO 99/61906, Abbott; *Jacobs et al., Mol. Biochem. Parasitol. 91, 237-49*) and GRA3 (*Robben et al. 2002, J. Biol. Chem. 277, 17544-47*): the rhoptry antigens ROP1 (or P66) (US 5,976,553, U. Leland; EP 0 431 541, Innogenetics) and ROP2 (or P54) (*Sharma et al., J. Immunol., 131, 377-83*).

As described in the above-mentioned references, the antigens were obtained with recombinant cDNA techniques in expression vectors. For example, for the antigen SAG1, WO 98/08700 uses known expression vectors in phage lambda-gt11. WO 98/12683 uses the same phage and transfects *E. coli* with a proprietary plasmid, or by preparing a special expression cassette, as in WO 96/02654. EP 0 724 016 obtains mimotopes using combinatorial expression libraries of peptides. EP 0 301 961 describes how to obtain excretion-secretion antigens with molecular weights ranging from 20 kDa to 185 kDa. WO 89/05658 describes a protein containing the epitopes of the 24 kDa protein recognized by the antibodies produced against *Toxoplasma* excretion-secretion antigens; this protein is obtained by transfection of cells by means of expression vectors. WO 03/080839 describes a method based on phage-display technology for identifying antigen fragments of *T. gondii* proteins and their use as diagnostic and immunogenic agents. The antigen P28 (GRA2) is described in US 5,633,139 and the method of obtaining it is again implemented through

expression in phage lambda-gt11. The antigen P32 (GRA6) is described in patent FR 2,702,491, the antigen ROP1 (P66) in US patent 5,976,553, P35 (or GRA8) in EP 0 431 541, WO 99/57295 and WO 99/61906, and lastly P68 in EP 0 431 541.

Yang et al. (Parasitol. Res. , 2004, 92: 58-64) describe a chimeric protein containing SAG1 and SAG2 and its use to develop immunity against *T. gondii* in mice.

Chinese Patent 11 94991C discloses a recombinant fusion protein containing two toxoplasma antigens (GRA6 and p30). No data are reported to show that assays based on this recombinant fusion protein display the required sensitivity in IgG- and IgM-based tests.

During the last ten years, several studies have reported the use of recombinant antigens for the serological diagnosis of *T. gondii* infection. Nevertheless, although promising none of the assays based on recombinant antigens displayed all the characteristics required to replace the tachyzoite antigen in IgG- and IgM-based tests, indicating that further work is needed before an immunoassay employing recombinant products will be available for clinical purposes.

Thus the main aim of the studies in this filed is to improve the performance of enzyme-linked immunoassays based on recombinant products, thus improving, for example early diagnosis of congenital toxoplasmosis in newborns/infants.

SUMMARY OF THE INVENTION

It has now been found that the combination of antigenic regions of *Toxoplasma gondii* proteins, in the form of recombinant fusion products, retains the antigenic properties of the individual antigen fragments. The corresponding chimeric proteins thus produced can be used for diagnostic and therapeutic purposes.

The use of said chimeric antigens as diagnostic agents and the related diagnostic aids containing them, for example in the form of enzyme-linked immunoassays or kits, constitute a further object of the present invention.

Another object of the present invention are the gene sequences coding for the above-mentioned chimeric antigens, their use as medicaments, particularly for the prevention and therapy of *Toxoplasma gondii* infection, e.g. as gene therapy. The present invention also extends to the gene sequences that hybridize with the sequences of the above-mentioned chimeric antigens in stringent hybridization conditions.

Another object of the present invention is the use of the chimeric antigens as medicaments, particularly in the form of vaccines, which are useful for the prevention and cure of the infection. The vaccines according to the present invention are suitable for use in humans and other animals (particularly pig, cat, sheep).

These and other objects will be illustrated here below in detail, also by means of examples and figures.

DETAILED DESCRIPTION OF THE INVENTION

The main object of the present invention is, therefore, the provision of recombinant chimeric antigens obtained through the fusion of different antigenic regions of *Toxoplasma gondii* gene products, and the use of the recombinant proteins thus obtained for developing selective diagnostic and therapeutic means.

The main advantages of the present invention over the other types of antigens or antigen fragments known in the literature as reported above are the following

and are evident when these antigens are used in diagnostic immunoassays on sample sera for detection of the infection:

- With respect to the use of the entire *Toxoplasma gondii* antigen, prepared from the parasite as lysed, whole-cell extract, the chimeric recombinant antigens have the advantage of avoiding unspecific reactions due to the presence of other non-proteinaceous material and of providing a better reproducibility. Moreover, some natural protein antigens of the parasite are insoluble and, consequently, are poorly represented in commercial assays employing the lysed, whole-cell extract of *T. gondii.*
- With respect to the use of single antigenic regions or single antigen fragments (as described in WO 03/080839), the recombinant chimeric antigens show the advantage of improving the sensitivity of the assays in which they are used. In other words their use decreases or abolishes the occurrence of false negative responses.

A) With respect to the use of a mixture or a collection of single antigenic regions (as also envisaged in WO 03/080839), the advantages are least two. From the point of view of the industrial applicability and production is much easier to produce a single engineered construct containing three or more antigen regions rather than separately produce each single fragment and subsequently assemble them by an economic and reproducible method. Secondly, as already said before, the use of the chimeric recombinant antigens of the invention improves the sensitivity of the assays.

These and other advantages are shown in the Examples section.

In particular the present invention relates to a chimeric recombinant antigen containing the fusion at least three different antigenic regions of *Toxoplasma gondii,* wherein said antigenic regions are B-cell epitopes, which bind to *Toxoplasma gondii*-specific antibodies. Preferably the *Toxoplasma gondii*-specific antibodies are extracted from sera of subjects who have been infected by *Toxoplasma gondii.*

More particularly the present invention covers a chimeric antigen, wherein the three different antigenic regions have an amino acid sequence selected from the group consisting of: SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 33, SEQ ID NO: 34, SEQ ID NO: 35, SEQ ID NO: 36, SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40, SEQ ID NO: 41 and SEQ ID NO: 42. Preferred sequences in the above group are SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10 and SEQ ID NO: 12.

For example the chimeric antigen of the invention comprises the amino acid sequence of SEQ ID NO: 28 or the amino acid sequence of SEQ ID NO: 30 or the amino acid sequence of SEQ ID NO: 32.

The chimeric antigens of the present invention may be engineered using known methods. The fusions may be direct (the C-terminus of one amino acid sequence is linked to the N-terminal of the other through a simple covalent bond) or they may employ a flexible linker domain, such as the hinge region of human IgG, or polypeptide linkers consisting of small amino acids such as glycine, serine, threonine or alanine, at various lengths and combinations. For example the linker may be a polyglycine repeat interrupted by serine or threonine at a certain interval. Preferably, the linker is composed by three glycine residues and two serine residues, giving the aminoacid sequence Ser-Gly-Gly-Gly-Ser (SGGGS linker).

Additionally, the chimeric antigens of the invention may be tagged by His-His-His-His-His-His (His6), to allow rapid purification by metal-chelate chromatography, and/or by epitopes to which antibodies are available, to allow for detection on western blots, immunoprecipitation, or activity depletion/blocking in bioassays.

Another object of the present invention is a nucleotide sequence coding for the chimeric antigen as defined above. According to a preferred embodiment of the invention such nucleotide sequence comprises at least three different nucleotide sequences selected from the group consisting of: SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9 and SEQ ID NO: 11. According to a more preferred embodiment, such nucleotide sequence comprises the nucleotide sequence of SEQ ID NO: 27 or the nucleotide sequence of SEQ ID NO: 29 or the nucleotide sequence of SEQ ID NO: 31.

Also included in the scope of the present invention are nucleotide sequences that hybridizes with any sequence described above under stringent hybridization conditions, as well the corresponding chimeric recombinant antigen encoded by such hybridized nucleotide sequence.

The chimeric antigens of the present invention may be prepared by cloning and expression in a prokaryotic or eukaryotic expression system, using the appropriate expression vectors. Any method known in the art can be employed.

For example the DNA molecules coding for the antigens of the invention are inserted into appropriately constructed expression vectors by techniques well known in the art (see Sambrook et al, 1989). Such vectors are another object of the present invention.

In order to be capable of expressing the desired protein (in this case the chimeric antigens), an expression vector should comprise also specific nucleotide sequences containing transcriptional and translational regulatory information linked to the DNA coding the desired protein in such a way as to permit gene expression and production of the protein. First in order for the gene to be transcribed, it must be preceded by a promoter recognizable by RNA polymerase, to which the polymerase binds and thus initiates the transcription

process. There are a variety of such promoters in use, which work with different efficiencies (strong and weak promoters).

For eukaryotic hosts, different transcriptional and translational regulatory sequences may be employed, depending on the nature of the host. They may be derived form viral sources, such as adenovirus, bovine papilloma virus, Simian virus or the like, where the regulatory signals are associated with a particular gene, which has a high level of expression. Examples are the TK promoter of the Herpes virus, the SV40 early promoter, the yeast gal4 gene promoter, etc. Transcriptional initiation regulatory signals may be selected which allow for repression and activation, so that expression of the genes can be modulated. All these hosts are a further object of the present invention.

Nucleic acid molecules which encode the chimeric antigens of the invention may be ligated to a heterologous sequence so that the combined nucleic acid molecule encodes a fusion protein. Such combined nucleic acid molecules are included within the embodiments of the invention. For example, they may be joined to the DNA coding for a protein which allows purification of the chimeric antigen by only one step of affinity chromatography. This joined/fused protein may be for example Glutathione Sulpho Transferase (GST) to generate fusion products at the carboxy terminus of GST protein. The corresponding recombinant proteins expressed in the cytoplasm of transformed *E. coli* cells may be purified by affinity chromatography using a Glutathione-Sepharose resin.

The DNA molecule comprising the nucleotide sequence coding for the chimeric molecule of the invention is inserted into vector(s), having the operably linked transcriptional and translational regulatory signals, which is capable of integrating the desired gene sequences into the host cell. The cells which have been stably transformed by the introduced DNA can be selected by also introducing one or more markers which allow for selection of host cells which

contain the expression vector. The marker may also provide for phototrophy to an auxotropic host, biocide resistance, e.g. antibiotics, or heavy metals such as copper, or the like. The selectable marker gene can either be directly linked to the DNA gene sequences to be expressed, or introduced into the same cell by co-transfection. Additional elements may also be needed for optimal synthesis of proteins of the invention.

Factors of importance in selecting a particular plasmid or viral vector include: the ease with which recipient cells, that contain the vector may be recognized and selected form those recipient cells which do not contain the vector; the number of copies of the vector which are desired in a particular host; and whether it is desirable to be able to "shuttle" the vector between host cells of different species.

Once the vector(s) or DNA sequence containing the construct(s) has been prepared for expression the DNA construct(s) mat be introduced into an appropriate host cell by any of a variety of suitable means: transformation, transfection, conjugation, protoplast fusion, electroporation, calcium phosphate-precipitation, direct microinjection, etc.

Host cells may be either prokaryotic or eukaryotic. Example of eukaryotic hosts are mammalian cells, such as human, monkey, mouse, and Chinese hamster ovary (CHO) cells. Expression in these host cells provides post-translational modifications to protein molecules, including correct folding or glycosylation at correct sites. Also yeast cells can carry out post-translational peptide modifications including glycosylation. A number of recombinant DNA strategies exist which utilize strong promoter sequences and high copy number of plasmids which can be utilized for production of the desired proteins in yeast. Yeast recognizes leader sequences on cloned mammalian gene products and secretes peptides bearing leader sequences (i.e., pre-peptides). Example of prokaryotic hosts are bacteria, such as *Escherichia coli.*

After the introduction of the vector(s), the host cells are grown in a selective medium, which selects for the growth of vector-containing cells. Expression of the cloned gene sequence(s) results in the production of the desired proteins.

Purification of the recombinant antigens is carried out by any one of the methods known for this purpose, i.e. any conventional procedure involving extraction, precipitation, chromatography, electrophoresis, or the like. A further purification procedure that may be used in preference for purifying the antigens of the invention is affinity chromatography using monoclonal antibodies which bind the target protein and which are produced and immobilized on a gel matrix contained within a column. Impure preparations containing the recombinant protein are passed through the column. The antigens will be bound to the column by the specific antibody while the impurities will pass through. After washing, the antigen is eluted from the gel by a change in pH or ionic strength.

Another aspect of the present invention is the process for the recombinant production of the chimeric antigen as described above, comprising culturing the host cell transformed with the vector containing the nucleotide sequence of the invention and isolating the desired product.

A further object of the present invention is a DNA molecule comprising the DNA sequence coding for the above fusion protein, as well as nucleotide sequences substantially the same.

"Nucleotide sequences substantially the same" includes all other nucleic acid sequences which, by virtue of the degeneracy of the genetic code, also code for the given amino acid sequence.

Another object of the present invention is a nucleotide sequence which hybridizes to the complement of the nucleotide sequence coding for the

chimeric antigen of the invention under highly stringent or moderately stringent conditions, as long as the antigen obtained maintains the same biological activity, i.e. ability to bind to antibodies against the parasite.

The term "hybridization" as used here refers to the association of two nucleic acid molecules with one another by hydrogen bonding. Typically, one molecule will be fixed to a solid support and the other will be free in solution. Then, the two molecules may be placed in contact with one another under conditions that favour hydrogen bonding. Factors that affect this bonding include: the type and volume of solvent; reaction temperature; time of hybridization; agitation; agents to block the non-specific attachment of the liquid phase molecule to the solid support (Denhardt's reagent or BLOTTO); the concentration of the molecules; use of compounds to increase the rate of association of molecules (dextran sulphate or polyethyleneglycol); and the stringency of the washing conditions following hybridization.

Stringency conditions are a function of the temperature used in the hybridization experiment, the molarity of the monovalent cations and the percentage of formamide in the hybridization solution. To determine the degree of stringency involved with any given set of conditions, one first uses the equation of Meinkoth et al. (1984) for determining the stability of hybrids of 100% identity expressed as melting temperature Tm of the DNA-DNA hybrid: Tm = 81.5°C + 16.6 (LogM) + 0.41 (%GC) - 0.61 (% form) - 500/L, where M is the molarity of monovalent cations, %GC is the percentage of G and C nucleotides in the DNA, % form is the percentage of formamide in the hybridization solution, and L is the length of the hybrid in base pairs. For each 1°C that the Tm is reduced from that calculated for a 100% identity hybrid, the amount of mismatch permitted is increased by about 1%. Thus, if the Tm used for any given hybridization experiment at the specified salt and formamide concentrations is 10°C below the Tm calculated for a 100% hybrid according to equation of Meinkoth, hybridization will occur even if there is up to about 10% mismatch.

As used herein, highly stringent conditions are those which are tolerant of up to about 15% sequence divergence, while moderately stringent conditions are those which are tolerant of up to about 20% sequence divergence. Without limitation, examples of highly stringent (12-15°C below the calculated Tm of the hybrid) and moderately (15-20°C below the calculated Tm of the hybrid) conditions use a wash solution of 2 X SSC (standard saline citrate) and 0.5% SDS at the appropriate temperature below the calculated Tm of the hybrid. The ultimate stringency of the conditions is primarily due to the washing conditions, particularly if the hybridization conditions used are those which allow less stable hybrids to form along with stable hybrids. The wash conditions at higher stringency then remove the less stable hybrids. A common hybridization condition that can be used with the highly stringent to moderately stringent wash conditions described above is hybridization in a solution of 6 X SSC (or 6 X SSPE), 5 X Denhardt's reagent, 0.5% SDS, 100 µg/ml denatured, fragmented salmon sperm DNA at a temperature approximately 20°C to 25°C below the Tm. If mixed probes are used, it is preferable to use tetramethyl ammonium chloride (TMAC) instead of SSC (Ausubel, 1987-1998).

The term "nucleic acid molecule" also includes analogues of DNA and RNA, such as those containing modified backbones.

The nucleic acid molecules of the invention also include antisense molecules that are partially complementary to nucleic acid molecules encoding antigens of the present invention and that therefore hybridize to the encoding nucleic acid molecules (hybridization). Such antisense molecules, such as oligonucleotides, can be designed to recognise, specifically bind to and prevent transcription of a target nucleic acid encoding a polypeptide of the invention, as will be known by those of ordinary skill in the art (see, for example, Cohen, J.S., Trends in Pharm. Sci., 10,435 (1989), Okano, J. Neurochem. 56, 560 (1991); O'Connor,

J. Neurochem 56,560 (1991); Lee et al., Nucleic Acids Res 6,3073 (1979); Cooneyetal., Science 241, 456(1988); Dervan et al., Science 251, 1360 (1991).

According to the terminology used herein, a composition containing a compound [X] is "substantially free of" impurities [herein, Y] when at least 85% by weight of the total X+Y in the composition is X. Preferably, X comprises at least about 90% by weight of the total of X+Y in the composition, more preferably at least about 95%, 98% or even 99% by weight.

Another aspect of the invention is the use of chimeric antigens described above as medicaments. In particular, one of the main objects of the invention is use of chimeric antigens as active ingredients for the preparation of medicaments for the prevention or treatment of *Toxoplasma gondii* infections.

In the case of *gene therapy* another object of the invention is the use of the nucleotide sequences coding for the antigens of the invention as medicaments, in particular for the preparation of medicaments useful for the treatment and prevention of *Toxoplasma gondii* infections.

The pharmaceutical compositions should preferably comprise a therapeutically effective amount of the chimeric antigens of the invention or the corresponding nucleotide sequence. Chimeric antigens of the invention may thus act as vaccines for the prevention or the treatment of *Toxoplasma gondii* infection.

For the therapeutic application, where the preparation of medicaments or vaccines comes within the framework of general knowledge for further reference the reader is again referred to the patent literature cited in the present description and, particularly, to *Beghetto et al., The Journal of Infectious Diseases, 2005, 191:637-645.*

The term "therapeutically effective amount" as used herein refers to an amount of a therapeutic agent needed to treat, ameliorate, or prevent a targeted disease or condition, or to exhibit a detectable therapeutic or preventative effect. For any compound, the therapeutically effective dose can be estimated initially either in cell culture assays, for example, of neoplastic cells, or in animal models, usually mice, rabbits, dogs, or pigs.

The animal model may also be used to determine the appropriate concentration range and route of administration. Such information can then be used to determine useful doses and routes for administration in humans.

The precise effective amount for a human subject will depend upon the severity of the disease state, general health of the subject, age, weight, and gender of the subject, diet, time and frequency of administration, drug combination (s), reaction sensitivities, and tolerance/response to therapy. This amount can be determined by routine experimentation and is within the judgement of the clinician. Generally, an effective dose will be from 0.01 mg/kg to 50 mg/kg, preferably 0.05 mg/kg to 10 mg/kg. Compositions may be administered individually to a patient or may be administered in combination with other agents, drugs or hormones.

A pharmaceutical composition may also contain a pharmaceutically acceptable carrier, for administration of a therapeutic agent. Such carriers include antibodies and other polypeptides, genes and other therapeutic agents such as liposomes, provided that the carrier does not itself induce the production of antibodies harmful to the individual receiving the composition, and which may be administered without undue toxicity.

Suitable carriers may be large, slowly metabolised macromolecules such as proteins, polysaccharides, polylactic acids, polyglycolic acids, polymeric amino

acids, amino acid copolymers and inactive virus particles.

Pharmaceutically acceptable salts can be used therein, for example, mineral acid salts such as hydrochlorides, hydrobromides, phosphates, sulphates, and the like; and the salts of organic acids such as acetates, propionates, malonates, benzoates, and the like. A thorough discussion of pharmaceutically acceptable carriers is available in Remington's Pharmaceutical Sciences (Mack Pub. Co. , N. J.1991).

Pharmaceutically acceptable carriers in therapeutic compositions may additionally contain liquids such as water, saline, glycerol and ethanol. Additionally, auxiliary substances, such as wetting or emulsifying agents, pH buffering substances, and the like, may be present in such compositions. Such carriers enable the pharmaceutical compositions to be formulated as tablets, pills, dragees, capsules, liquids, gels, syrups, slurries, suspensions, and the like, for ingestion by the patient.

Once formulated, the compositions of the invention can be administered directly to the subject. The subjects to be treated can be animals; in particular, human subjects can be treated.

The pharmaceutical compositions utilised in this invention may be administered by any number of routes including, but not limited to, oral, intravenous, intramuscular, intra- arterial, intramedullary, intrathecal, intraventricular, transdermal ortranscutaneous applications (for example, see W098/20734), subcutaneous, intraperitoneal, intranasal, enteral, topical, sublingual, intravaginal or rectal means. Gene guns or hyposprays may also be used to administer the pharmaceutical compositions of the invention. Typically, the therapeutic compositions may be prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid vehicles prior to injection may also be prepared.

Direct delivery of the compositions will generally be accomplished by injection,subcutaneously, intraperitoneally, intravenously or intramuscularly, or delivered to the interstitial space of a tissue. The compositions can also be administered into a lesion.

Dosage treatment may be a single dose schedule or a multiple dose schedule.

The method of treating a mammal suffering from *Toxoplasma-gondii* infection, comprising administering a therapeutically effective amount of the vaccine as described above represents one of the aspects of the present invention.
A further object of the present invention is the use of chimeric antigens as described above as active agents for the diagnosis of *Toxoplasma gondii* infections, in particular for the diagnosis of the time of infection.

Also the kits for the diagnosis of *Toxoplasma gondii* infection, containing at least one chimeric antigen according are part of the present invention. Such kits amy be useful for the diagnosis of an acute and/or chronic *Toxoplasma gondii* infection.

The chimeric antigen of the invention may be employed in virtually any assay format that employs a known antigen to detect antibodies. A common feature of all of these assays is that the antigen is contacted with the body component suspected of containing antibodies under conditions that permit the antigen to bind to any such antibody present in the component. Such conditions will typically be physiologic temperature, pH and ionic strength using an excess of antigen. The incubation of the antigen with the specimen is followed by detection of immune complexes comprised of the antigen.

Design of the immunoassays is subject to a great deal of variation, and many formats are known in the art. Protocols may, for example, use solid supports, or

immunoprecipitation. Most assays involve the use of labeled antibody or polypeptide; the labels may be, for example, enzymatic, fluorescent, chemiluminescent, radioactive, or dye molecules. Assays which amplify the signals from the immune complex are also known; examples of which are assays which utilize biotin and avidin, and enzyme-labeled and mediated immunoassays, such as ELISA assays.

The immunoassay may be, without limitation, in a heterogenous or in a homogeneous format, and of a standard or competitive type. In a heterogeneous format, the polypeptide is typically bound to a solid matrix or support to facilitate separation of the sample from the polypeptide after incubation.

Examples of solid supports that can be used are nitrocellulose (e.g., in membrane or microtiter well form), polyvinyl chloride (e.g., in sheets or microtiter wells), polystyrene latex (e.g., in beads or microtiter plates, polyvinylidine fluoride (known as Immulon™), diazotized paper, nylon membranes, activated beads, and Protein A beads. For example, Dynatech Immulon™1 or Immulon™2 microtiter plates or 0.25 inch polysterene beads (Precision Plastic Ball) can be used in the heterogeneous format. The solid support containing the antigenic polypeptides is typically washed after separating it from the test sample, and prior to detection of bound antibodies. Both standard and competitive formats are known in the art.

In a homogeneous format, the test sample is incubated with the combination of antigens in solution. For example, it may be under conditions that will precipitate any antigen-antibody complexes which are formed. Both standard and competitive formats for these assays are known in the art.

In a standard format, the amount of antibodies forming the antibody-antigen complex is directly monitored. This may be accomplished by determining

whether labeled anti-xenogenic (e.g., anti-human) antibodies which recognize an epitope on anti-*Toxoplasma gondii* antibodies will bind due to complex formation. In a competitive
format, the amount of antibodies in the sample is deduced by monitoring the competitive effect on the binding of a known amount of labeled antibody (or other competing ligand) in the complex.

Complexes formed comprising anti- *Toxoplasma gondii* antibody (or, in the case of competitive assays, the amount of competing antibody) are detected by any of a number of known techniques, depending on the format. For example, unlabeled antibodies in the complex may be detected using a conjugate of antixenogeneic Ig complexed with a label, (e.g., an enzyme label).

In an immunoprecipitation or agglutination assay format the reaction between the chimeric antigens and the antibody forms a network that precipitates from the solution or suspension and forms a visible layer or film of precipitate. If no anti-*Toxoplasma gondii* antibody is present in the test specimen, no visible precipitate is formed.

The chimeric antigens of the invention will typically be packaged in the form of a kit for use in these immunoassays. The kit will normally contain in separate containers the combination of antigens (either already bound to a solid matrix or separate with reagents for binding them to the matrix), control antibody formulations (positive and/or negative), labeled antibody when the assay format requires same and signal generating reagents (e.g., enzyme substrate) if the label does not generate a signal directly. Instructions (e.g., written, tape, VCR, CD-ROM, etc.) for carrying out the assay usually will be included in the kit.

The diagnostic kits, which are the object of the present invention, are therefore known to the expert in the field. By way of an example, the reader is referred to

the patent literature cited above, to which may be added US 6,265,176, WO 01/63283, and WO 03/080839 as further references.

The invention will now be illustrated in greater detail by means of examples and figures.

DESCRIPTION OF THE FIGURES

Figure 1. Plasmid map of the bacterial expression vector pGEX-SN.

Figure 2. Schematic representation of the chimeric antigens.
The DNA sequences of clones Tx-2.a, Tx-1.16, Tx-4.18, Tx-15.11, Tx-1.11 and Tx-11.b, respectively encoding for protein fragments of the *T. gondii* genes MIC2, MIC3, SAG1, GRA3, GRA7 and M2AP were used for the construction of GST-EC2, GST-EC3 and GST-EC4 fusion proteins.

Figure 3. Expression of *T. gondii* chimeric antigens in *E. coli* cells.
SDS-PAGE analysis of purified GST-EC2, GST-EC3 and GST-EC4 fusion proteins. The recombinant proteins were subjected to electrophoresis (0,003 mg/lane) on 12% acrylamide gel. MW, molecular weight markers.

Figure 4. Biochemical characterisation of the chimeric antigens
HPLC analysis of the purified GST-EC2 performed by gel filtration using the TSK G4000 SW-XL column.

Figure 5. Antigenic properties of individual protein fragments within the chimeric antigens.
Immunoreactivity of individual Tx-2.a, Tx-1.16, Tx-4.18, Tx-15.11, Tx-1.11 and Tx-11.b antigen fragments, and of EC2, EC3 and EC4 chimeric antigens with serum samples from *T. gondii* infected individuals. Sera were used either as

whole speciments (serum) or after depletion of specific antibodies against combinations of antigen fragments (Tx-1.16/Tx-4.18 depletion, Tx-2.a/Tx-4.18 depletion, etc.).

Figure 6. Immunoreactivity of the chimeric antigens with *Toxoplasma*-specific IgM antibodies

A) IgM Rec-ELISA analysis performed with *Toxoplasma*-specific IgM-positive (C+) and IgM-negative (C-) serum samples (sera dilution, 1:100) by varying the concentration of the biotin-labeled GST-EC2 and GST-EC3 antigens.

B) IgM Rec-ELISA analysis performed with serial dilutions of *Toxoplasma*-specific IgM-positive (from 1:100 to 1:6400) and IgM-negative (the control serum, diluted 1:100) serum samples, assayed with the biotin-labeled GST-EC2 and the mixture of GST-EC2 /GST-EC3.

Figure 7. Long-term stability of the chimeric antigens

IgM Rec-ELISA analysis performed with the biotin-labeled GST-EC2 and GST-EC3 antigens, which have been maintained at +4°C for different time intervals (days). Results are expressed as the ratio of the Optical Densities measured with the *Toxoplasma*-specific IgM-positive (OD C+) and IgM-negative (OD C-) serum samples.

EXAMPLES

The following Table 1 gives, by way of examples, the DNA sequences used for the construction of recombinant *Toxoplasma gondii* chimeric antigens:

Table 1

Name	Sequence	Identification	Classification
Tx-15.11 (SEQ ID 1)	GCTGCCTTGGGAGGCCTTGCGGCGGATC AGCCTGAAAATCATCAGGCTCTTGCAGAA CCAGTTACGGGTGTGGGGGAAGCAGGA GTGTCCCCCGTCAACGAAGCTGGTGAGT CATACAGTTCTGCAACTTCGGGTGTCCAA GAAGCTACCGCCCCAGGTGCAGTGCTCC TGGACGCAATCGATGCCGAGTCGGATAA GGTGGACAATCAGGCGGAGGGAGGTGA GCGTATGAAGAAGGTCGAAGAGGAGTTG TCGTTATTGAGGCGGGAATTATATGATCG CACAGATCGCCCTGGT	GRA 3	Dense granule protein
Tx-1.11 (SEQ ID 3)	CAGTTCGCTACCGCGGCCACCGCGTCAG ATGACGAACTGATGAGTCGAATCCGAAAT TCTGACTTTTTCGATGGTCAAGCACCCGT TGACAGTCTCAGACCGACGAACGCCGGT GTCGACTCGAAAGGGACCGACGATCACC TCACCACCAGCATGGATAAGGCATCTGTA GAGAGTCAGCTTCCGAGAAGAGAGCCAT TGGAGACGGAGCCAGATGAACAAGAAGA AGTTCAT	GRA 7	Dense granule protein
Tx-1.16 (SEQ ID 5)	AGGAGGACTGGATGTCATGCCTTCAGGG AGAACTGCAGCCCTGGTAGATGTATTGAT GACGCCTCGCATGAGAATGGCTACACCT GCGAGTGCCCCACAGGGTACTCACGTGA GGTGACTTCCAAGGCGGAGGAGTCGTGT GTGGAAGGAGTCGAAGTCACGCTGGCTG AGAAATGCGAGAAGGAATTCGGCATCAG CGCGTCATCCTGCAAATGCGAT	MIC 3	Microneme protein

Tx-4.18 (SEQ ID 7)	CCATCGGTCGTCAATAATGTCGCAAGGT GCTCCTACGGTGCAGACAGCACTCTTGG TCCTGTCAAGTTGTCTGCGGAAGGACCC ACTACAATGACCCTCGTGTGCGGGAAAG ATGGAGTCAAAGTTCCTCAAGACAACAAT CAGTACTGTTCCGGGACGACGCTGACTG GTTGCAACGAGAAATCGTTCAAAGATATT TTGCCAAAATTAACTGAGAACCCGTGGCA GGGTAACGCTTCGAGTGATAAGGGTGCC ACGCTAACGATCAAGAAGGAAGCATTTCC AGCCGAGTCAAAAAGCGTCATTATTGGAT GCACAGGGGGATCGCCTGAGAAGCATCA CTGTACCGTGAAACTGGAGTTTGCCGGG GCTGCAGGGTCAGCAAAATCGGCT	SAG 1	Surface protein
Tx-2.a (SEQ ID 9)	CCCCAGGATGCCATTTGCTCGGATTGGT CCGCATGGAGCCCCTGCAGTGTATCCTG CGGTGACGGAAGCCAAATCAGGACGCGA ACTGAGGTTTCTGCTCCGCAACCTGGAA CACCAACATGTCCGGACTGCCCTGCGCC CATGGGAAGGACTTGCGTGGAACAAGGC GGACTTGAAGAAATCCGTGAATGCAGTG CGGGGGTATGTGCTGTTGACGCTGGATG TGGCGTCTGGGTT	MIC2	Microneme protein

Tx-11.b (SEQ ID 11)	AACGAACCGGTGGCCCTAGCTCAGCTCA GCACATTCCTCGAGCTCGTCGAGGTGCC ATGTAACTCTGTTCATGTTCAGGGGGTGA TGACCCCGAATCAAATGGTCAAAGTGACT GGTGCAGGATGGGATAATGGCGTTCTCG AGTTCTATGTCACGAGGCCAACGAAGAC AGGCGGGGACACAAGCCGAAGCCATCTT GCGTCGATCATGTGTTATTCCAAGGACAT TGACGGCGTGCCGTCAGACAAAGCGGGA AAGTGCTTTCTGAAGAACTTTTCTGGTGA AGACTCGTCGGAAATAGACGAAAAAGAA GTATCTCTACCCATCAAGAGCCACAACGA TGCGTTCATGTTCGTTTGTTCTTCAAATGA TGGATCCGCACTCCAGTGTGATGTTTTCG CCCTTGATAACACCAACTCTAGCGACGG GTGGAAAGTGAATACCGTGGATCTTGGC GTCAGCGTTAGTCCGGATTTGGCATTCG GACTCACTGCAGATGGGGTCAAGGTGAA GAAGTTGTACGCAAGCAGCGGCCTGACA GCGATCAACGACGACCCTTCCTTGGGGT GCAAGGCTCCTCCCCATTCTCCGCCGGC CGGAGAGGAACCGAGTTTGCCGTCGCCT GAAAACAGCGGGTCTGCAACACCAGCGG AAGAAAGTCCGTCTGAGTCTGAATCT	M2AP	Microneme protein

The sequence Tx-15.11 constitutes a fragment of the gene GRA3 (*Bermudes et al., Mol. Biochem. Parasitol., 1994, 68:247-257*). Said clone has the amino acid sequence

AALGGLAADQPENHQALAEPVTGVGEAGVSPVNEAGESYSSATSGVQEATA PGAVLLDAIDAESDKVDNQAEGGERMKKVEEELSLLRRELYDRTDRPG (SEQ ID 2) and its use in chimeric antigens is covered by the present invention.

The sequence Tx-1.11 constitutes a fragment of the antigen GRA7 (*Bonhomme et al., J. Histochem. Cytochem., 1998, 46:1411-1421*). Said clone has the amino acid sequence

ATAATASDDELMSRIRNSDFFDGQAPVDSLRPTNAGVDSKGTDDHLTTSMDK ASVESQLPRREPLETEPDEQEEVHF (SEQ ID 4) and its use in chimeric antigens is covered by the present invention.

The sequence Tx-1.16 constitutes a fragment of the MIC3 gene (*Garcia-Réguet et al., Cellular Microbiol., 2000, 2:353-364*). Said clone has the amino acid sequence RRTGCHAFRENCSPGRCIDDASHENGYTCECPTGYSREVTSKAEESCVEGV EVTLAEKCEKEFGISASSCKCD (SEQ ID 6) and its use in chimeric antigens is covered by the present invention.

The sequence Tx-4.18 constitutes a fragment of the antigen SAG1 (*Burg et al., J. Immunol., 1988, 141:3584-3591*). Said clone has the amino acid sequence PSVVNNVARCSYGADSTLGPVKLSAEGPTTMTLVCGKDGVKVPQDNNQYCS GTTLTGCNEKSFKDILPKLTENPWQGNASSDKGATLTIKKEAFPAESKSVIIGC TGGSPEKHHCTVKLEFAGAAGSAKSA (SEQ ID 8) and its use in chimeric antigens is covered by the present invention.

The sequence Tx-2.a represents a fragment of the MIC2 gene (*Wan et al, Mol. Biochem.Parasitol., 1997, 84:203-214*). Said clone has the amino acid sequence PQDAICSDWSAWSPCSVSCGDGSQIRTRTEVSAPQPGTPTCPDCPAPMGRT CVEQGGLEEIRECSAGVCAVDAGCGVWV (SEQ ID 10) and its use in chimeric antigens is covered by the present invention.

The sequence Tx-11.b represents a distinct fragment of the M2AP gene (*Rabenau et al., Mol. Microbiol., 2001, 41:537-547*). Said clone has the amino acid sequence NEPVALAQLSTFLELVEVPCNSVHVQGVMTPNQMVKVTGAGWDNGVLEFYV TRPTKTGGDTSRSHLASIMCYSKDIDGVPSDKAGKCFLKNFSGEDSSEIDEKE VSLPIKSHNDAFMFVCSSNDGSALQCDVFALDNTNSSDGWKVNTVDLGVSVS

PDLAFGLTADGVKVKKLYASSGLTAINDDPSLGCKAPPHSPPAGEEPSLPSPE NSGSATPAEESPSESES (SEQ ID 12) and its use in chimeric antigens is covered by the present invention.

Construction of chimeric antigens

EC2 protein product is a chimeric molecule containing the DNA sequences Tx-2.a, Tx-1.16 and Tx-4.18.

SEQ ID 9 was used as template for DNA amplification of clone Tx-2.a by using oligonucleotides K551 (5'-GGACTAGTCGGCTCCCCCAGGATGCC-3') and K553 (5'-CATCCAGTCCTGCTACCGCCACCAGACCAGACGCCACATCC AGC-3'). The oligonucleotide K553 contains a sequence encoding for the linker SGGGS, which joins the sequences Tx-2.a and Tx-1.16. PCR condition was 30" at 94°C, 30" at 50°C and 60" at 72°C for 20 cycles.

SEQ ID 5 was used as template for DNA of clone Tx-1.16 by using oligonucleotides K552 (5'-GTGGCGTCTGGTCTGGTGGCGGTAGCAG GACTGGATGTCATGCC-3') and K555 (5'-TGACGACCGAGCTAC CGCCACCAGAGTTATCGCATTTGCAGGATG-3'). The oligonucleotide K555 contains a sequence encoding for the linker SGGGS, which joins the sequences Tx-1.16 and Tx-4.18. PCR condition was 30" at 94°C, 30" at 50°C and 60" at 72°C for 20 cycles.

SEQ ID 7 was used as template for DNA amplification of clone Tx-4.18 by using oligonucleotides K554 (5'-ATGCGATAACTCTGGTGGCGG TAGCTCGGTCGTCAATAATGTCGC-3') and K556 (5'-CCGCGGCC GCTAGCCGATTTTGCTGACCCTG-3'). PCR condition was 30" at 94°C, 30" at 50°C and 60" at 72°C for 20 cycles.

The PCR products were purified by means of the "Qiagen Purification Kit" (Qiagen, CA, USA). 25 ng of DNA amplification products of SEQ ID 9 and SEQ ID 5 were mixed together and used as templates in PCR reaction by using oligonucleotides K551 and K555. PCR condition was 30" at 94°C, 30" at 50°C and 60" at 72°C for 20 cycles. 25 ng of the resulting DNA amplification was purified with "Qiagen Purification Kit" (Qiagen, CA, USA) and then mixed with

25 ng of DNA amplification product of SEQ ID 4. Finally, the DNA mixture was used as template for DNA amplification by using oligonucleotides K551 and K556, following PCR condition of 30" at 94°C, 30" at 50°C and 90" at 72°C for 20 cycles.

EC3 protein product is a chimeric molecule containing the DNA sequences Tx-15.11, Tx-1.11 and Tx-11.b.

SEQ ID 1 was used as template for DNA amplification of clone Tx-15.11 by using oligonucleotides K563 (5'-GGACTAGTCGGCTGG CTGCCTTGGGAGGCCTTG-3') and K565 (5'-GCCGCGGTAGCACTACCG CCACCAGACAAACCAGGGCGATCTGTG-3'). The oligonucleotide K565 contains a sequence encoding for the linker SGGGS, which joins the sequences Tx-15.11 and Tx-1.11. The PCR protocol was 30" at 94°C, 30" at 48°C and 60" at 72°C for 20 cycles.

SEQ ID 3 was used as template for DNA amplification of clone Tx-1.11 by using oligonucleotides K564 (5'-GCCCTGGTTTGTCTGGTGGCGGTAG TGCTACCGCGGCCACCGCG-3') and K567 (5'-CCGGTTCGTTACTACCG CCACCAGAGAAATGAACTTCTTCTTGTTC-3'). The oligonucleotide K567 contains a sequence encoding for the linker SGGGS, which joins the sequences Tx-1.11 and Tx-11.b. The PCR protocol was 30" at 94°C, 30" at 48°C and 60" at 72°C for 20 cycles.

SEQ ID 11 was used as template for DNA amplification of clone Tx-11.b by using oligonucleotides K566 (5'-GAAGTTCATTTCTCTGGTGGCG GTAGTAACGAACCGGTGGCCCTAG-3') and K568 (5'-CCGCGGCCGC AGATTCAGACTCAGACGGAC-3'). The PCR protocol was 30" at 94°C, 30" at 45°C and 60" at 72°C for 20 cycles.

The PCR products were purified by means of the "Qiagen Purification Kit" (Qiagen, CA, USA). 25 ng of DNA amplification products of SEQ ID 1 and SEQ ID 3 were mixed together and used as templates in PCR reaction by using oligonucleotides K563 and K567. The PCR protocol was 30" at 94°C, 30" at 45°C and 60" at 72°C for 30 cycles. 25 ng of the resulting DNA amplification

was purified and then mixed with 25 ng of DNA amplification product of SEQ ID 11. Finally, the DNA mixture was used as template for DNA amplification by using oligonucleotides K563 and K568, following PCR condition of 30" at 94°C, 30" at 45°C and 180" at 72°C for 30 cycles.

EC4 protein product is a chimeric molecule containing the DNA sequences Tx-2.a, Tx-1.16 and Tx-11.b.

SEQ ID 9 was used as template for DNA amplification of clone Tx-2.a using oligonucleotides K551 and K553.

SEQ ID 5 was used as template for DNA amplification of clone Tx-1.16 by using oligonucleotides K552 and K572 (5'-CGTTACTACCGC CACCAGAGTTATCGCATTTGCAGGATGA-3'). The oligonucleotide K572 contains a sequence encoding for the linker SGGGS, which joins the sequences Tx-1.16 and Tx-11.b.

SEQ ID 11 was used as template for DNA amplification of clone Tx-11.b by using oligonucleotides K571 (5'-TAACTCTGGTGGCGGTAGT AACGAACCGGTGGCCCTAGC-3') and K568.

The PCR products were purified as by using "Qiagen Purification Kit" (Qiagen, CA, USA). 25 ng of DNA amplification products of SEQ ID 9 and SEQ ID 5 were mixed together and used as templates in PCR reaction by using oligonucleotides K551 and K572. 25 ng of the resulting DNA amplification was purified and then mixed with 25 ng of DNA amplification product of SEQ ID 11. Finally, the DNA mixture was used as template for DNA amplification by using oligonucleotides K551 and K568. PCR conditions for the construction of EC4 were the same that those used for EC2 and EC3 constructs.

The following Table 2 gives, by way of examples, the DNA sequences of the EC2, EC3 and EC4 chimeric antigens:

Table 2

Name	Sequence
EC2 SEQ ID 27	ACTAGTCGGCTCCCCCAGGATGCCATTTGCTCGGATTGGTC CGCATGGAGCCCCTGCAGTGTATCCTGCGGTGACGGAAGC CAAATCAGGACGCGAACTGAGGTTTCTGCTCCGCAACCTGG AACACCAACATGTCCGGACTGCCCTGCGCCCATGGGAAGGA CTTGCGTGGAACAAGGCGGACTTGAAGAAATCCGTGAATGC AGTGCGGGGGTATGTGCTGTTGACGCTGGATGTGGCGTCT GGTCTGGTGGCGGTAGCAGGACTGGATGTCATGCCTTCAG GGAGAACTGCAGCCCTGGTAGATGTATTGATGACGCCTCGC ATGAGAATGGCTACACCTGCGAGTGCCCCACAGGGTACTCA CGTGAGGTGACTTCCAAGGCGGAGGAGTCGTGTGTGGAAG GAGTCGAAGTCACGCTGGCTGAGAAATGCGAGAAGGAATTC GGCATCAGCGCGTCATCCTGCAAATGCGATAACTCTGGTGG CGGTAGCTCGGTCGTCAATAATGTCGCAAGGTGCTCCTACG GTGCAGACAGCACTCTTGGTCCTGTCAAGTTGTCTGCGGAA GGACCCACTACAATGACCCTCGTGTGCGGGAAAGATGGAGT CAAAGTTCCTCAAGACAACAATCAGTACTGTTCCGGGACGA CGCTGACTGGTTGCAACGAGAAATCGTTCAAAGATATTTTGC CAAAATTAACTGAGAACCCGTGGCAGGGTAACGCTTCGAGT GATAAGGGTGCCACGCTAACGATCAAGAAGGAAGCATTTCC AGCCGAGTCAAAAAGCGTCATTATTGGATGCACAGGGGGAT CGCCTGAGAAGCATCACTGTACCGTGAAACTGGAGTTTGCC GGGGCTGCAGGGTCAGCAAAATCGGCTAGCGGCCGC

EC3 SEQ ID 29

ACTAGTCGGCTGGCTGCCTTGGGAGGCCTTGCGGATCAGC
CTGAAAATCATCAGGCTCTTGCAGAACCAGTTACGGGTGTG
GGGGAAGCAGGAGTGTCCCCCGTCAACGAAGCTGGTGAGT
CATACAGTTCTGCAACTTCGGGTGTCCAAGAAGCTACCGCC
CCAGGTGCAGTGCTCCTGGACGCAATCGATGCCGAGTCGG
ATAAGGTGGACAATCAGGCGGAGGGAGGTGAGCGTATGAA
GAAGGTCGAAGAGGAGTTGTCGTTATTGAGGCGGGAATTAT
ATGATCGCACAGATCGCCCTGGTTTGTCTGGTGGCGGTAGT
GCTACCGCGGCCACCGCGTCAGATGACGAACTGATGAGTC
GAATCCGAAATTCTGACTTTTTCGATGGTCAAGCACCCGTTG
ACAGTCTCAGACCGACGAACGCCGGTGTCGACTCGAAAGG
GACCGACGATCACCTCACCACCAGCATGGATAAGGCATCTG
TAGAGAGTCAGCTTCCGAGAAGAGAGCCATTGGAGACGGAG
CCAGATGAACAAGAAGAAGTTCATTTCTCTGGTGGCGGTAG
TAACGAACCGGTGGCCCTAGCTCAGCTCAGCACATTCCTCG
AGCTCGTCGAGGTGCCATGTAACTCTGTTCATGTTCAGGGG
GTGATGACCCCGAATCAAATGGTCAAAGTGACTGGTGCAGG
ATGGGATAATGGCGTTCTCGAGTTCTATGTCACGAGGCCAA
CGAAGACAGGCGGGGACACAAGCCGAAGCCATCTTGCGTC
GATCATGTGTTATTCCAAGGACATTGACGGCGTGCCGTCAG
ACAAAGCGGGAAAGTGCTTTCTGAAGAACTTTTCTGGTGAAG
ACTCGTCGGAAATAGACGAAAAAGAAGTATCTCTACCCATCA
AGAGCCACAACGATGCGTTCATGTTCGTTTGTTCTTCAAATG
ATGGATCCGCACTCCAGTGTGATGTTTTCGCCCTTGATAACA
CCAACTCTAGCGACGGGTGGAAAGTGAATACCGTGGATCTT
GGCGTCAGCGTTAGTCCGGATTTGGCATTCGGACTCACTGC
AGATGGGGTCAAGGTGAAGAAGTTGTACGCAAGCAGCGGC
CTGACAGCGATCAACGACGACCCTTCCTTGGGGTGCAAGGC
TCCTCCCCATTCTCCGCCGGCCGGAGAGGAACCGAGTTTGC
CGTCGCCTGAAAACAGCGGGTCTGCAACACCAGCGGAAGA
AAGTCCGTCTGAGTCTGAATCTGCGGCCGCGG

EC4 SEQ ID 31

ACTAGTCGGCTCCCCCAGGATGCCATTTGCTCGGATTGGTC
CGCATGGAGCCCCTGCAGTGTATCCTGCGGTGACGGAAGC
CAAATCAGGACGCGAACTGAGGTTTCTGCTCCGCAACCTGG
AACACCAACATGTCCGGACTGCCCCGCGCCCATGGGAAGG
ACTTGCGTGGAACAAGGCGGACTTGAAGAAATCCGTGAATG
CAGTGCGGGGGTATGTGCTGTTGACGCTGGATGTGGCGTCT
GGTCTGGTGGCGGTAGCAGGACTGGATGTCATGCCTTCAG
GGAGAACTGCCGCCCTGGTAGATGTATTGATGACGCCTCGC
ATGAGAATGGCTACACCTGCGAGTGCCCCACATGGTACTCA
CGTGAGGTGACTTCCAAGGCGGAGGAGTCGTGTGTGGAAG
GAGTCGAAGTCACGCTGGCTGAGAAATGCGAGAAGGAATTC
GGCATCAGCGCGTCCTCCTGCAAATGCGATAACTCTGGTGG
CGGTAGTAACGAACCGGTGGCCCTAGCTCAGCTCAGCACAT
TCCTCGAGCTCGTCGAGGTGCCATGTAACTCTGTTCATGTTC
AGGGGGTGATGACCCCGAATCAAATGGTCAAAGTGACTGGT
GCAGGATGGGATAATGGCGTTCTCGAGTTCTATGTCACGAG
GCCAACGAAGACAGGCGGGGACACAAGCCGAAGCCACCTT
GCGTCGATCATGTGTTATTCCAAGGACATTGACGGCGTGCC
GTCAGACAAAGCGGGAAAGTGCTTTTTGAAGAACTTTTCTGG
TGAAGACTCGTCGGAAATAGACGAAAAAGAAGTATCTCTACC
CATCAAGAGCCACAACGATGCGTTCATGTTCGTTTGTTCTTC
AAATGATGGATCCGCACTCCAGTGTGATGTTTTCGCCCTTGA
TAACACCAACTCTAGCGACGGGTGGAAAGTGAATACCGTGG
ATCTTGACGTCAGCGTTAGTCCGGATTTGGCATTCGGACTCA
CTGCAGATGGGGTCAAGGTGAAGAAGTTGTACGCAAGCAGC
GGCCTGACAGCGATCAACGACGACCCTTCCTTGGGGTGCAA
GGCTCCTCCCCATTCTCCGCCGGCCGGAGAGGAACCGAGT
TTGCCGTCGCCTGAAAACAGCGGGTCTGCAACACCAGCGGA
AGAAAGTCCGTCTGAGTCTGAATCTGCGGCCGCGG

The chimeric protein EC2 has the amino acid sequence TSRLPQDAICSDWSAWSPCSVSCGDGSQIRTRTEVSAPQPGTPTCPDCPAP MGRTCVEQGGLEEIRECSAGVCAVDAGCGVWSGGGSRTGCHAFRENCSPG RCIDDASHENGYTCECPTGYSREVTSKAEESCVEGVEVTLAEKCEKEFGISAS SCKCDNSGGGSSVVNNVARCSYGADSTLGPVKLSAEGPTTMTLVCGKDGVK VPQDNNQYCSGTTLTGCNEKSFKDILPKLTENPWQGNASSDKGATLTIKKEAF PAESKSVIIGCTGGSPEKHHCTVKLEFAGAAGSAKSASGR (SEQ ID 28) and its use as recombinant antigen, containing multiple *Toxoplasma gondii* protein fragments, is covered by the present invention.

The chimeric protein EC3 has the amino acid sequence TSRLAALGGLADQPENHQALAEPVTGVGEAGVSPVNEAGESYSSATSGVQE ATAPGAVLLDAIDAESDKVDNQAEGGERMKKVEEELSLLRRELYDRTDRPGL SGGGSATAATASDDELMSRIRNSDFFDGQAPVDSLRPTNAGVDSKGTDDHLT TSMDKASVESQLPRREPLETEPDEQEEVHFSGGGSNEPVALAQLSTFLELVE VPCNSVHVQGVMTPNQMVKVTGAGWDNGVLEFYVTRPTKTGGDTSRSHLA SIMCYSKDIDGVPSDKAGKCFLKNFSGEDSSEIDEKEVSLPIKSHNDAFMFVCS SNDGSALQCDVFALDNTNSSDGWKVNTVDLGVSVSPDLAFGLTADGVKVKKL YASSGLTAINDDPSLGCKAPPHSPPAGEEPSLPSPENSGSATPAEESPSESES AAA (SEQ ID 30) and its use as recombinant antigen, containing multiple *Toxoplasma gondii* protein fragments, is covered by the present invention.

The chimeric protein EC4 has the amino acid sequence TSRLPQDAICSDWSAWSPCSVSCGDGSQIRTRTEVSAPQPGTPTCPDCPAP MGRTCVEQGGLEEIRECSAGVCAVDAGCGVWSGGGSRTGCHAFRENCRPG RCIDDASHENGYTCECPTWYSREVTSKAEESCVEGVEVTLAEKCEKEFGISAS SCKCDNSGGGSNEPVALAQLSTFLELVEVPCNSVHVQGVMTPNQMVKVTGA GWDNGVLEFYVTRPTKTGGDTSRSHLASIMCYSKDIDGVPSDKAGKCFLKNF SGEDSSEIDEKEVSLPIKSHNDAFMFVCSSNDGSALQCDVFALDNTNSSDGW KVNTVDLDVSVSPDLAFGLTADGVKVKKLYASSGLTAINDDPSLGCKAPPHSP PAGEEPSLPSPENSGSATPAEESPSESESAAA (SEQ ID 32) and its use as

recombinant antigen, containing multiple *Toxoplasma gondii* protein fragments, is covered by the present invention.

Construction of DNA vectors directing the expression of chimeric antigens as fusion products with GST in the cytoplasm of *E. coli* cells

DNA fragments encoding for the EC2, EC3 and EC4 chimeric proteins were cloned as fusion products with the protein Glutathione Sulpho Transferase (GST) and expressed as soluble proteins in the cytoplasm of bacterial cells, for the purpose of determining their specificity and selectivity. DNA sequences of EC2, EC3 and EC4 (SEQ ID 27, 29 and 31, respectively) were digested with the restriction enzymes *SpeI* and *NotI*. Digested DNA were cloned into vector pGEX-SN *(Minenkova et al., International Journal of Cancer, 2003, 106:534-44)*, which was previously digested with *SpeI* and *NotI* endonucleases, to generate fusion products at the carboxy terminus of GST protein. The resulting plasmids were used to transform competent *E.coli* cells following standard protocols (*Sambrook et al., 1989, Molecular Cloning, Cold Spring Harbor Laboratory Press, Cold Spring Harbor*).

Biochemical characterisation of the recombinant chimeric antigens

The recombinant proteins GST-EC2, GST-EC3 and GST-EC4 were expressed in the cytoplasm of transformed *E. coli* cells and purified by affinity chromatography using Glutathione-Sepharose resin (Amersham Pharmacia Biotech, Sweden), following the manufacturer's instructions. Protein purity and concentration were assessed by SDS-PAGE (Sodium Dodecyl Sulphate-Poly-acrylammide Gel Electrophoresis) analysis and Bradford assay, respectively. The affinity-purified recombinant products were dialyzed against PBS, diluted at a concentration of 1 mg/ml with PBS and stored at –20°C until use. The yield of purified products were 8 mg/liter of bacterial culture, 5 mg/liter and 4 mg/liter for the chimeric antigens GST-EC2, GST-EC3 and GST-EC4, respectively. The recombinant proteins were subsequently subjected to high-performance liquid chromatography (HPLC) analysis. To this aim a gel filtration was performed using a TSK G4000 SW-XL HPLC-column, by injecting 30 µl of each samples (protein concentration, 2mg/ml) into the column with a flow rate of 1 ml/min

(mobile phase: KH_2PO_4 0,05 M; NaCl 0,3 M pH 7.0). Results from HPLC analysis demonstrated that the chimeric antigens GST-EC2, GST-EC3 and GST-EC4 were purified as homogeneous products in dimeric forms (see Figure 4 were the HPLC analysis of GST-EC2 is shown as an example), with a respective molecular weight of 110,4, 152,6 and 130 kDa (Da, Dalton). Protein aggregates of high molecular weight were absent in all of the purified protein preparations.

Immunoreactivity of the chimeric recombinant antigens with IgG antibodies from sera of *T. gondii* infected individuals: IgG Rec-ELISA

The ELISA performance of the GST fusion products was performed by coating Maxisorp-multiwells plates (Nunc) with single antigen fragments or chimeric proteins at a concentration of 5 µg/ml in coating buffer (50 mM $NaHCO_3$, pH 9.6). After incubation overnight at 4°C plates were incubated for 1 h at 37°C with blocking buffer (5% non-fat dry milk, 0.05% Tween-20 in PBS) and subsequently incubated for 1 h at 37°C with sera from *T. gondii* seropositive and seronegative individuals, diluted 1:200 in blocking solution. Plates were extensively washed with 0.05% Tween-20 in PBS and anti-human-IgG horse-radish peroxidase-conjugated antibodies (1 mg/ml; Sigma-Aldrich, USA), diluted 1:10000 in blocking solution, was then added to each well. Finally, incubating plates with the chromogenic substrate tetramethylbenzidine (TMB; Sigma-Aldrich, USA) revealed the enzymatic activity. Results were recorded as the difference between the absorbance (Optical Density, OD) at 450 and 620 nm, detected by an automated ELISA reader (Labsystem Multiskan, Finland). For each serum sample the assay was done in triplicate and average values were calculated.

The following Table 3 shows the IgG reactivity of the single antigen fragments and EC2, EC3 and EC4 chimeric antigens, expressed as GST fusion proteins, by using sera from 36 (T1-T36) *T. gondii*-seropositive and 27 (N1-N27) *T. gondii*-seronegative humans. The *Toxoplasma*-specific IgG levels, calculated as

International Units (IU) using a commercial assay (VIDAS system, bioMerieux, Marcy-l'Etoile, France) are reported. For every GST-fusion product the cut-off value was determined as the mean plus two times the standard deviation of the absorbency readings obtained from the *Toxoplasma* IgG negative sera. Normal type, OD<cut-off; bold type, OD>cut-off. The numerical value reported into each cell was calculated as the ratio of the test OD to the cut-off of the corresponding antigen (nd, not determined). Values greater than 1 indicate a positive response.

Table 3 clearly shows that some of the sera which are positive result to be negative when using single antigenic fragments, whereas they result to be positive (correctly) when using the chimeric antigens of the present invention. Please note that the numerical values of IgG concentrations obtained with the standard assay cannot be compared with the others, because they have been calculated by reference to an International Standard, which cannot be used for the other assays.

Table 3

Serum sample	IgG levels (IU/ml)	Recombinant GST-fusion proteins								
		Tx-15.11	Tx-1.11	Tx-1.16	Tx-4.18	Tx-2.a	Tx-11.b	EC2	EC3	EC4
T1	>300	7,4	3,5	9,8	3,7	18,3	12,5	11,0	10,0	7,6
T2	188	8,7	7,4	2,4	5,1	18,8	4,4	26,0	23,5	20,0
T3	265	7,4	2,8	4,6	2,8	8,4	5,6	20,4	17,9	34,0
T4	4090	23,3	27,8	22,4	29,7	25,1	27,4	33,6	43,3	40,5
T5	>300	12,4	9,7	25,7	2,9	nd	nd	30,6	34,4	19,5
T6	35	1,2	0,8	1,0	1,3	0,9	1,4	1,4	5,7	1,7
T7	58	1,0	1,3	0,6	2,3	1,2	1,0	4,6	5,1	1,2
T8	101	2,5	0,9	2,5	2,8	11,2	2,9	17,0	4,8	30,9
T9	88	16,2	5,9	2,4	2,7	6,8	6,7	9,4	27,4	29,9
T10	188	1,7	1,2	4,4	3,1	1,7	1,3	4,4	3,6	3,3
T11	530	28,9	12,7	12,1	31,4	32,1	31,2	32,1	42,6	41,5
T12	89	0,9	nd	4,8	nd	1,2	0,5	1,7	2,4	2,1
T13	1095	8,6	2,3	3,4	5,9	nd	nd	31,7	23,4	20,3
T14	248	12,6	4,3	2,1	0,9	nd	nd	7,4	14,6	9,2
T15	155	17,5	1,0	2,8	3,4	nd	nd	6,7	20,1	13,0
T16	427	4,5	3,9	5,0	2,7	nd	nd	17,4	37,9	18,9
T17	236	12,1	4,8	6,1	3,7	nd	nd	22,0	33,9	12,7
T18	46	2,1	2,0	2,6	2,2	nd	nd	1,9	5,4	1,4
T19	247	2,3	2,5	3,6	0,5	nd	nd	3,7	3,9	2,3
T20	100	nd	nd	nd	nd	7,5	1,4	13,1	5,2	14,6
T21	27	2,6	0,6	4,1	1,0	nd	nd	3,1	4,8	5,5
T22	>300	28,6	5,1	4,6	19,9	nd	nd	14,5	14,8	7,4
T23	92	1,7	1,1	1,3	0,8	0,7	0,8	6,9	4,5	6,4
T24	68	0,5	2,1	2,0	2,6	1,3	1,3	2,5	6,6	1,4
T25	63	2,4	2,4	5,5	6,8	8,8	7,7	13,8	16,6	32,9
T26	299	12,1	10,0	6,5	4,6	nd	nd	10,0	13,5	6,0
T27	108	3,4	4,0	5,7	3,0	nd	nd	4,8	6,2	3,1
T28	68	1,7	2,7	3,3	2,1	2,0	2,3	6,4	6,9	7,7
T29	>300	1,0	1,1	2,8	1,2	4,0	6,3	9,1	13,7	23,5
T30	114	1,8	2,8	19,3	3,8	3,9	2,0	13,0	13,3	13,6
T31	35	3,2	1,2	3,5	0,9	1,5	1,0	3,6	6,3	5,7
T32	300	4,8	16,0	17,3	20,9	nd	nd	31,6	33,1	8,4
T33	123	5,6	2,6	3,3	4,5	20,4	2,8	25,8	21,0	36,6
T34	60	nd	nd	nd	nd	6,2	4,2	9,1	7,7	9,3
T35	155	0,7	2,4	0,5	2,3	1,8	1,1	7,3	10,4	9,5
T36	45	0,3	1,6	1,1	0,8	1,2	0,9	3,2	3,2	3,1
N1		0,4	0,4	0,7	0,7	0,5	0,3	0,4	0,7	0,5
N2		0,7	0,5	0,5	0,4	nd	nd	0,4	0,5	0,4
N3		nd	nd	nd	nd	nd	nd	0,9	0,5	0,6
N4		nd	nd	nd	nd	nd	nd	0,4	0,5	0,7
N5		nd	nd	nd	nd	0,5	0,7	0,4	0,5	0,5
N6		nd	nd	nd	nd	nd	nd	0,4	0,5	0,5
N7		0,4	0,4	0,6	0,7	nd	nd	1,0	0,5	0,7
N8		0,4	0,5	0,5	0,5	nd	nd	0,4	0,5	0,6
N9		0,4	0,6	0,7	0,5	nd	nd	0,4	0,5	0,4
N10		nd	nd	nd	nd	nd	nd	0,3	0,5	0,4
N11		nd	nd	nd	nd	nd	nd	0,4	0,5	0,5
N12		nd	nd	nd	nd	nd	nd	0,5	0,7	0,8
N13		nd	nd	nd	nd	nd	nd	0,4	0,7	0,3
N14		0,7	0,5	0,5	0,5	0,9	0,7	0,5	0,5	0,5
N15		0,4	0,6	0,4	1,0	0,5	0,8	0,4	0,5	0,4
N16		0,8	0,2	0,5	0,6	0,5	0,4	0,5	0,7	0,5
N17		0,8	0,5	0,9	0,4	0,6	0,7	0,4	0,5	0,6
N18		0,3	0,4	0,7	0,5	0,6	0,6	0,4	0,6	0,9
N19		0,4	0,5	0,5	0,8	nd	nd	0,5	0,8	0,8
N20		0,6	0,6	0,4	0,6	0,7	0,5	0,8	0,7	1,0
N21		0,7	0,7	0,6	0,5	0,5	0,4	0,4	0,7	0,6
N22		0,4	0,5	0,7	0,5	0,5	0,7	0,4	0,6	0,3
N23		0,5	0,5	0,7	0,5	nd	nd	0,4	0,6	0,5
N24		nd	nd	nd	nd	0,5	0,5	0,5	0,7	0,7
N25		nd	nd	nd	nd	0,8	0,5	0,8	0,6	0,5
N26		nd	nd	nd	nd	0,5	0,6	0,4	0,6	0,4
N27		nd	nd	nd	nd	0,4	0,6	0,8	1,0	0,4

The following Table 4 summarizes the results of the ELISA assays based on recombinant proteins, employing serum samples from *T. gondii* seropositive and seronegative humans. In each column are reported the number and the corresponding percentages of reactive sera. From Table 4 it clearly results that the sensitivity of the assay (see the 2nd column reporting the occurrence of false negatives) is improved when using the chimeric antigens of the invention. This improvement is evident with respect to both the use of single antigenic fragments and the use of a collection or mixtures (Mix-Tx-1.16/Tx-4.18/Tx-2.a, Mix-Tx-1.16/Tx-4.18/Tx-2.a, Mix-Tx-1.16/Tx-2.a/Tx-11.b) of the single different antigenic fragments.

Table 4

GST-fusion protein	**Sera from *T.gondii* infected subjects**	**Sera from *T. gondii* uninfected subjects**
Tx-15.11	28/34 (82,4%)	0/15
Tx-1.11	29/33 (87,9%)	0/15
Tx-1.16	31/34 (91,2%)	0/15
Tx-4.18	27/33 (81,8%)	0/15
Tx-2.a	21/23 (91,3%)	0/14
Tx-11.b	18/23 (78,3%)	0/14
Mix-Tx-1.16/Tx-4.18/Tx-2.a	35/36 (97,2)	0/27
Chimera EC2	36/36 (100%)	0/27
Mix-Tx-15.11/Tx-1.11/Tx-11.b	35/36 (97,2%)	0/27
Chimera EC3	36/36 (100%)	0/27
Mix-Tx-1.16/Tx-2.a/Tx-11.b	34/36 (94,4%)	0/27
Chimera EC4	36/36 (100%)	0/27

Immunoreactivity of single antigenic domains within the chimeric recombinant antigens with IgG antibodies of sera from *T. gondii* infected individuals

To verify that the chimeric antigens retain the immunoreactivity of the single antigen fragments used for their construction, human sera that specifically reacted, in ELISA assays, with single antigen fragments, were adsorbed with different combinations of single antigens and then assayed with the chimeric proteins. To this aim, distinct combinations of the antigen fragments, expressed as GST-fusion products, were coated onto Maxisorb-multiwells plates (Nunc) at a concentration of 10 µg/ml in coating buffer (50 mM $NaHCO_3$, pH 9.6) and then incubated overnight at 4°C. The plates were extensively washed and subsequently incubated for 30 min. at 37°C with serum samples (20 µl/well) in blocking solution (5% non-fat dry milk, 0.05% Tween-20 in PBS). The fragment-specific antibody-depleted sera were recovered from each well, added to a new well, incubated for 30 min., and the same procedure was repeated 6 more times. Samples that have been depleted for specific antibodies against a single or multiple antigen fragments were finally analyzed by ELISA assays on the chimeric antigens. For this purpose, the chimeric antigens EC2, EC3 and EC4, as GST-fusion products, were coated overnight at 4°C onto Maxisorb-multiwells plates at a concentration of 5 µg/ml. The coated plates were blocked and subsequently incubated for 1 h at 37°C with the antibody-depleted human sera diluted 1:100 in blocking solution. Plates were extensively washed and anti-human-IgG alkaline phosphatase-conjugated antibodies (Sigma-Aldrich, USA), diluted 1:7500 in blocking solution, was then added to each well. Finally, the chromogenic substrate p-nitrophenyl phosphate (Sigma-Aldrich, USA) revealed the enzymatic activity. The results were recorded as the difference between the absorbance at 405 and 620 nm, detected by an automated ELISA reader (Labsystem Multiskan, Finland). For each sample the assay was done in duplicate and average values were calculated.

Biochemical modification of EC2 and EC3 chimeric antigens

To analyze the immunoreactivity of the chimeric antigens EC2 and EC3 with specific anti-*Toxoplasma* IgM antibodies in patient sera, the recombinant proteins were chemically modified by biotinilation. To this aim, the purified GST-EC2 and GST-EC3, diluted at a concentration of 1 mg/ml in PBS were incubated in the presence of a five-fold molar excess of sulfosuccinimidyl-6-(biotin-amido)hexanoate (Sulfo-NHS-LC-Biotin from Pierce, USA) for 3 hours on ice. The proteins were then dialyzed overnight against PBS to remove excess of non-reacted and hydrolyzed biotin reagents. Levels of biotin incorporation into chimeric antigens was determined by using "EZ Biotin Quantitation Kit" (Pierce, USA), resulting in 1.4 biotin/molecule for GST-EC2 and 1.3 biotin/molecule for GST-EC3. The biotin-labeled products were finally diluted at a concentration of 0.5 mg/ml and stored at –20°C until use.

Immunoreactivity of the biotin-labeled EC2 and EC3 with *Toxoplasma*-specific IgM antibodies: IgM Rec-ELISA

To investigate the immunoreactivity of recombinant antigens with *Toxoplasma*-specific immunoglobulins M, a double-sandwich immunoassay was employed (IgM Rec-ELISA). Maxisorb plates (Nunc, USA) were coated with anti-human IgM antibodies (Sigma-Aldrich, USA) at a concentration of 10 µg/ml in coating buffer (50 mM $NaHCO_3$, pH 9.6). Plates were blocked with 3% bovine serum albumin in PBS (blocking solution) for 1h at 37°C and subsequently incubated for 1 h at 37°C with serum samples in blocking solution. Plates were washed and then incubated for 2 h at room temperature with the biotin-labeled GST-fusion proteins, diluted in blocking solution. After being extensively washed the plates were incubated for 1h at room temperature with horseradish peroxidase-conjugated streptavidin (Pierce, USA) at a concentration of 1 µg/ml in blocking solution. Finally, the enzymatic activity was revealed incubating plates for 30 min. at room temperature with the substrate tetramethylbenzidine (Sigma-Aldrich, USA). Results were recorded as the difference between the absorbance at 450 and 620 nm, detected by an automated ELISA reader

(Labsystem Multiskan, Finland). For each sample the assay was done in duplicate and average values were calculated.

Thermal stability of the biotin-labeled chimeric antigens

In order to determine the thermal stability of the biotin-labeled GST-EC2 and GST-EC3, recombinant products were diluted at a concentration of 5 µg/ml in the commercial buffer "Stabilzyme" (SurModics, USA) and stored at +4°C until use. After different interval times (up to 80 days), the immunoreactivity of recombinant proteins in the IgM Rec-ELISA analysis was assessed and results obtained analyzing the corresponding products maintained frozen at –20°C were compared. The IgM Rec-ELISA was performed as described above, using the biotin-labeled GST-EC2 and GST-EC3 antigens at a final concentration of 500 ng/ml in blocking solution (3% BSA in PBS) and human sera diluted 1:100 in blocking solution. For each sample the assay was done in duplicate and average values were calculated. The ID50, calculated as day-limit when the 50% of toxoplasma-specific IgM-immunoreactivity was measured, were 189 days and 97 days for GST-EC2 and GST-EC3, respectively. These findings clearly indicate that the chimeric antigens of the invention are stable in diluted solutions for a long time, which a fundamental requisite for the commercial usefulness of a recombinant product.

Expanded evaluation of IgM Rec-ELISA

The biotin-labeled GST-EC2 and GST-EC3 chimeric antigens were assayed with IgM antibodies in sera from *T. gondii* infected individuals and the results of the IgM Rec-ELISAs were compared with those obtained with commercial assays employing lysed, whole-cell *Toxoplasma* antigen (VIDAS system from bioMerieux, France; ETI-TOXOK-M Reverse-PLUS from DiaSorin, Italy). To this aim, serum samples from women who acquired primary toxoplasmosis during gestation and referred for post-natal follow-up at the Center for Perinatal Infection of Campania Region, Italy, were assayed. The bioMerieux VIDAS Toxo IgG and IgM assays were used to select three groups of serum samples

for the Toxoplasma IgM Rec-ELISA performance evaluation. Group A (n = 22) was composed of samples negative for *T. gondii*-specific IgM and IgG antibody as measured by the VIDAS Toxo IgM and IgG assays. Group B (n = 18) was composed of samples with a serological profile consistent with a chronic infection (presence of *T. gondii*-specific IgG antibody and absence of *T. gondii*-specific IgM as measured by the VIDAS Toxo IgM and IgG assays, respectively). Group C (n = 50) was composed of samples with a serological profile consistent with an acute infection (presence of *T. gondii*-specific IgM and IgG antibodies as measured by the VIDAS Toxo IgM and IgG assays). IgM Rec ELISA was performed as described above and for each serum sample the assay was done in duplicate and average values were calculated.

The following Table 5 shows the IgM reactivity of the biotin-labeled GST-EC2 and GST-EC3 chimeric antigens, compared to the results obtained with commercial assays (VIDAS and ETI-TOXO-K), by using sera from group A (A1-A22), group B (B1-B18) and group C (C1-C50). The *Toxoplasma*-specific IgG levels, calculated as International Units (IU) are also reported. For each biotin-labeled GST-fusion product the cut-off was determined as the mean plus two times the standard deviation of the absorbency readings obtained from the *T. gondii*-specific IgM negative sera (groups A and B, n = 40). Cut-off values for VIDAS IgM, ETI-TOXOK-M Reverse-PLUS, GST-EC2 and GST-EC3 were 0,650, 0,500, 0,343 and 0,378, respectively. Values typed in bold indicate a positive response.

Table 5

Serum	Toxo-IgG (UI/ml)	VIDAS IgM	ETI-TOXOK-M Reverse-PLUS	IgM Rec-ELISA GST-EC2	IgM Rec-ELISA GST-EC3
A1	0	0,05	0,397	0,268	0,256
A2	4	0,22	0,317	0,263	0,270
A3	0	0,18	0,252	0,264	0,237
A4	0	0,05	0,375	0,324	0,241
A5	2	0,17	0,272	0,298	0,222
A6	0	0,03	0,288	0,270	0,234
A7	0	0,19	0,210	0,215	0,379
A8	0	0,10	0,108	0,203	0,296
A9	0	0,06	0,324	0,314	0,291
A10	0	0,09	0,339	0,325	0,286
A11	0	0,05	0,193	0,223	0,271
A12	2	0,08	0,134	0,268	0,378
A13	4	0,12	0,115	0,309	0,335
A14	0	0,23	0,115	0,221	0,286
A15	0	0,06	0,230	0,281	0,374
A16	2	0,08	0,132	0,317	0,269
A17	1	0,18	0,123	0,277	0,281
A18	0	0,35	0,097	0,316	0,279
A19	0	0,28	0,346	0,274	0,272
A20	0	0,09	0,054	0,259	0,132
A21	0	0,61	0,206	0,24	0,312
A22	0	0,06	0,127	0,238	0,233
B1	24	0,06	0,239	0,255	0,189
B2	10	0,09	0,076	0,283	0,304
B3	44	0,14	0,124	0,265	0,261
B4	44	0,28	0,195	0,298	0,216
B5	25	0,1	0,131	0,273	0,185
B6	57	0,12	0,164	0,296	0,293
B7	12	0,22	0,185	0,257	0,194
B8	58	0,12	0,148	0,255	0,248
B9	56	0,4	0,174	0,232	0,268
B10	19	0,09	0,068	0,290	0,194
B11	56	0,16	0,136	0,179	0,221
B12	45	0,12	0,139	0,235	0,181
B13	87	0,12	0,096	0,207	0,218
B14	27	0,15	0,144	0,196	0,174
B15	33	0,46	0,242	0,285	0,378
B16	13	0,04	0,064	0,161	0,177
B17	67	0,13	0,111	0,177	0,213
B18	53	0,27	0,170	0,238	0,165

Serum	Toxo-IgG (UI/ml)	VIDAS IgM	ETI-TOXOK-M Reverse-PLUS	IgM Rec-ELISA GST-EC2	IgM Rec-ELISA GST-EC3
C1	28	5,37	1,04	0,350	0,548
C2	255	3,86	1,49	0,546	0,498
C3	78	3,01	1,38	0,471	0,867
C4	1358	2,28	1,17	0,464	0,453
C5	178	2,31	1,27	0,598	0,406
C6	155	2,00	0,97	0,993	0,720
C7	109	3,20	1,76	0,794	0,642
C8	99	3,16	1,78	0,572	0,389
C9	103	2,28	1,34	1,056	1,222
C10	85	2,22	1,44	0,930	0,704
C11	70	1,01	0,79	0,416	0,376
C12	26	1,34	0,93	0,392	0,461
C13	36	1,22	0,86	0,532	0,499
C14	156	0,99	0,58	0,534	0,833
C15	204	0,93	0,90	0,810	0,710
C16	133	1,13	0,85	0,465	0,322
C17	183	1,14	0,82	0,320	0,327
C18	242	0,90	0,71	0,497	0,500
C19	80	1,00	0,79	0,444	0,706
C20	258	1,40	0,88	2,678	0,484
C21	278	1,69	1,06	0,703	0,509
C22	246	1,25	0,76	1,094	0,780
C23	59	1,23	0,71	0,495	1,499
C24	38	0,78	0,87	0,584	0,455
C25	130	0,76	0,92	0,562	0,545
C26	262	0,84	0,65	0,649	0,551
C27	168	0,96	0,85	1,439	0,938
C28	126	0,78	0,80	2,475	1,160
C29	197	1,38	0,61	0,544	0,358
C30	127	0,86	0,52	0,847	0,531
C31	72	1,28	0,93	1,756	0,891
C32	130	0,77	0,71	0,505	0,381
C33	439	1,00	0,66	0,834	0,464
C34	83	0,66	1,32	1,162	0,989
C35	178	0,89	0,87	0,694	0,487
C36	560	0,86	0,69	0,817	0,628
C37	223	0,96	0,73	0,531	0,819
C38	242	0,98	0,41	0,379	0,318
C39	118	1,16	0,84	0,420	0,380
C40	232	1,39	1,01	0,490	0,467
C41	213	1,03	1,05	0,750	0,822
C42	243	1,06	0,97	0,534	0,502
C43	154	0,75	0,73	0,455	0,337
C44	35	1,90	1,51	0,383	1,008
C45	667	0,85	1,01	0,366	0,285
C46	275	0,95	0,99	0,411	0,544
C47	157	1,93	1,36	0,382	0,464
C48	1037	1,08	0,51	0,385	0,301
C49	92	1,31	0,68	0,537	0,427
C50	255	0,69	0,69	0,354	0,801

The following Table 6 shows the performance characteristics of the commercial assays (VIDAS IgM and ETI-TOXOK-M Reverse PLUS), compared to the results obtained with the biotin-labeled EC2 and EC3 chimeric antigens (IgM Rec-ELISA). From Table 6 it clearly results that both specificity and positive predictive values of the assays (see the 3rd column reporting the occurrence of false positives) reached the maximum (100%) when using the chimeric antigens of the invention. With regard to sensitivity and agreement, both the commercial test ETI-TOXOK-M employing lysed, whole-cell *Toxoplasma* antigen and the IgM rec-ELISA with the chimeric antigen EC2 display identical performance characteristics, with both values very close to 100%.

Table 6

Diagnostic test	Sensitivity (%)	Specificity (%)	Agreement (%)	PPV* (%)	NPV* (%)
VIDAS IgM	100	100	100	100	100
ETI-TOXOK-M	98,0	100	98,9	100	97,6
EC2-IgM Rec-ELISA	98,0	100	98,9	100	97,6
EC3-IgM Rec-ELISA	84,0	100	91,1	100	83,3

* PPV, positive predictive value; NPV, negative predictive value.

Finally, the immunoreactivity of the biotin-labeled GST-EC2 and GST-EC3 antigens with IgM antibodies in sera from infants with congenital toxoplasmosis was investigated. In a retrospective study, sera from 30 infants of mothers with primary *T. gondii* infection during pregnancy were analyzed. Twenty infants had congenital toxoplasmosis and ten was uninfected, as demonstrated by the persistence or disappearance of *Toxoplasma*-specific IgG antibodies after 12 months of age, respectively. Within the infected patient cohort, the gestational age at the time of maternal infection was the second trimester in 6 mothers and the third trimester in 14 mothers. 30 serum samples from infected and uninfected infants were analyzed by IgM Rec-ELISA, and results obtained with commercial assays employing the whole-cell *Toxoplasma* antigen (ELFA-IgM

and ETI-TOXOK-M Reverse PLUS) were compared. Specific levels of anti-*Toxoplasma* IgG ranged from 28 to 1147 IU/ml for sera from infected infants and from 19 to 170 IU/ml for sera from uninfected subjects. For every GST-fusion product the cut-off value was determined as the mean plus 2SD of the absorbency readings obtained with sera from uninfected infants. In Table 7 are summarized the results of the IgM Rec-ELISAs with individual sera from infected infants. Overall, the number of IgM-reactive sera ranged from 70% (14/20) to 50%(10/20) using the GST-EC2 and GST-EC3 antigens, respectively. In contrast, only 7 out of 20 infected infants (35%) had positive results when ELFA-IgM or ETI-TOXOK-M assays were employed. Among uninfected infants, none of the sera recognized GST-EC2 and GST-EC3 antigens in the IgM Rec-ELISA or resulted to be positive using commercial assays.

In conclusion, these results demonstrate that the use of recombinant chimeric antigens is effective in distinguishing *T. gondii*-infected from uninfected individuals, having comparable or even better assay performance with respect of using the whole-cell tachyzoite antigen, and could provide the basis for standardized commercial immunoassays for toxoplasmosis serodiagnosis.

Table 7

Toxoplasma-specific IgM reactivity of serum samples from 30 infants born to mothers with primary *T.gondii* infection acquired during pregnancy [a]

Patient no.	Time after birth (wk)	Onset [b]	IgG levels (IU/ml)	ELFA-IgM cutoff [c]	ETI-ToxoM cutoff [c]	IgM Rec-ELISA cutoff [d]	
						GST-EC2	GST-EC3
T1	1	B	169	**6.41**	**2.66**	**2.479**	**0.542**
T2	2	B	988	**0.73**	0.15	**0.360**	**0.270**
T3	2	Sub	300	0.09	0.13	0.212	0.209
T4	3	Sub	57	0.05	0.23	0.206	0.211
T5	3	Sub	124	0.13	**1.62**	**0.641**	**1.103**
T6	4	Sub	218	0.04	0.09	**0.452**	**0.269**
T7	4	S	157	**2.61**	**1.62**	**1.522**	0.225
T8	4	S	172	**3.98**	**1.50**	**1.804**	**0.353**
T9	5	S	1147	0.07	0.10	**0.519**	0.206
T10	5	B	47	0.11	0.12	**0.272**	**0.276**
T11	6	Sub	28	0.10	0.18	**2.617**	**0.731**
T12	6	Sub	136	0.07	0.11	**0.314**	0.216
T13	7	S	209	**0.88**	**0.47**	**0.683**	0.217
T14	8	Sub	43	0.06	0.07	0.196	0.213
T15	8	B	160	**0.82**	0.08	0.206	0.219
T16	8	B	64	0.02	0.40	0.231	0.228
T17	8	Sub	145	0.31	**0.57**	**0.985**	**0.314**
T18	9	Sub	300	**6.37**	**1.30**	**0.548**	**0.315**
T19	12	Sub	196	0.05	0.17	**0.463**	**0.268**
T20	12	Sub	75	0.05	0.07	0.237	0.222
N1	5		90	0.38	0.06	0.237	0.218
N2	5		170	0.06	0.07	0.204	0.200
N3	5		66	0.23	0.09	0.238	0.235
N4	3		44	0.07	0.12	0.176	0.209
N5	9		41	0.05	0.05	0.209	0.193
N6	5		66	0.07	0.06	0.194	0.196
N7	8		13	0.09	0.06	0.193	0.201
N8	9		13	0.14	0.06	0.208	0.231
N9	6		19	0.28	0.07	0.184	0.215
N10	5		20	0.13	0.05	0.189	0.240

Notes to Table 7

[a] Serum samples from *T.gondii* infected (T1-T20) or uninfected children (N1-N10) were analyzed by IgM Rec-ELISAs with GST-EC2 and GST-EC3 antigens or by commercial assays (ELFA-IgM and ETI-TOXO-M).

[b] Severity of clinical onset: S. severe; B. benign; Sub. subclinical.

[c] Cutoff values for the ELFA-IgM and ETI-TOXO-M assays were 0.65 and 0.41 as indicated by manufacturers. respectively. Bold type, values > cutoff.

[d] Cutoff values for the IgM Rec-ELISA using GST-EC2 and GST-EC3 antigens were 0.25 and 0.26. respectively. Bold type, values > cutoff.

CLAIMS

1. A chimeric recombinant antigen containing the fusion of at least three different antigenic regions of *Toxoplasma gondii,* wherein said antigenic regions are B-cell epitopes, which bind to *Toxoplasma gondii*-specific antibodies.
2. The chimeric antigen of claim 1, wherein the *Toxoplasma gondii*-specific antibodies are extracted from sera of subjects who have been infected by *Toxoplasma gondii.*
3. The chimeric antigen of any preceding claim, wherein the three different antigenic regions are linked by a covalent bond or by a peptide linker.
4. The chimeric antigen of any preceding claim, wherein the three different antigenic regions have an amino acid sequence selected from the group consisting of: SEQ ID NO: 2, SEQ ID NO: 4, SEQ ID NO: 6, SEQ ID NO: 8, SEQ ID NO: 10, SEQ ID NO: 12, SEQ ID NO: 33, SEQ ID NO: 34, SEQ ID NO: 35, SEQ ID NO: 36, SEQ ID NO: 37, SEQ ID NO: 38, SEQ ID NO: 39, SEQ ID NO: 40, SEQ ID NO: 41 and SEQ ID NO: 42.
5. The chimeric antigen of any preceding claim, comprising the amino acid sequence of SEQ ID NO: 28.
6. The chimeric antigen according to any of claims 1 to 4, comprising the amino acid sequence of SEQ ID NO: 30.
7. The chimeric antigen according to any of claims 1 to 4, comprising the amino acid sequence of SEQ ID NO: 32.
8. A nucleotide sequence coding for the chimeric antigen according to any preceding claim.
9. The nucleotide sequence according to claim 8, comprising at least three different nucleotide sequences selected from the group consisting of: SEQ ID NO: 1, SEQ ID NO: 3, SEQ ID NO: 5, SEQ ID NO: 7, SEQ ID NO: 9 and SEQ ID NO: 11.
10. The nucleotide sequence according to claims 8 or 9, comprising the nucleotide sequence of SEQ ID NO: 27.

11. The nucleotide sequence according to claims 8 or 9, comprising the nucleotide sequence of SEQ ID NO: 29.
12. The nucleotide sequence according to claims 8 or 9, comprising the nucleotide sequence of SEQ ID NO: 31.
13. A nucleotide sequence that hybridizes with any sequence according to claims 8 to 12 under stringent hybridization conditions.
14. The chimeric recombinant antigen encoded by the nucleotide sequence of claim 13.
15. The nucleotide sequence of any claims from 8 to 13, which is a DNA sequence.
16. A vector comprising the DNA sequence of claim 15.
17. A host cell transformed with the vector of claim 16.
18. A process for the production of the chimeric antigen according to any claim from 1 to 7 or 14, comprising culturing the host cell of claim 17 and isolating the desired product.
19. Use of chimeric antigens according to any of claim from 1 to 7 or 14 as active agents for the diagnosis of *Toxoplasma gondii* infections.
20. Use according to claim 19 for the diagnosis of congenital toxoplasmosis in infants.
21. Use according to claim 19 for the diagnosis of the time of infection.
22. Kits for the diagnosis of *Toxoplasma gondii* infection, containing at least one chimeric antigen according to any claim from 1 to 7 or 14.
23. Kits for the diagnosis of an acute and/or chronic *Toxoplasma gondii* infection, containing at least one chimeric antigen according to any claim from 1 to 7 or 14.
24. Use of chimeric antigens according to any claim from 1 to 7 or 14 as medicaments.
25. Use of chimeric antigens of any claim from 1 to 7 or 14 as active ingredients for the preparation of medicaments for the prevention or treatment of *Toxoplasma gondii* infections.
26. Use of the nucleotide sequence of any claim from 8 to 13 as medicaments.

27. Use of the nucleotide sequence of any claim from 8 to 13 for the preparation of medicaments useful for the treatment or prevention of *Toxoplasma gondii* infections.
28. Pharmaceutical composition, particularly in the form of a vaccine, containing at least one chimeric antigen to any claim 1 to 7 or 14.
29. Pharmaceutical composition, particularly in the form of a vaccine, containing at least one nucleotide sequence according to any claim from 8 to13.
30. Composition according to claim 27 or 28 suitable for human and/or veterinary use.
31. A method of treating a mammal suffering from *Toxoplasma-gondii* infection, comprising administering a therapeutically effective amount of the vaccine of any claim from 27 to 29.