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### Original Article

## Expression of Plasmid Encoded GRA4 Gene of *Toxoplasma gondii* RH Strain in CHO Eukaryotic Cells

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#### **Abstract**

**Background:** Toxoplasmosis is a common infection all around the world. During pregnancy; it may lead to congenital disorders or abortion in human and animals. Severe damage of toxoplasmosis indicates to require effective vaccine. One of dense granules antigen is GRA4 that secrete from tachyzoite and bradyzoite. GRA4 genome is unique without intron and is one of the major immunogenic proteins from *Toxoplasma gondii*.

**Methods:** We confirmed the cloning of GRA4 gene into pcDNA3 by restriction enzyme and PCR of GRA4 gene with pcGRA4 plasmids as template. Then with using calcium- phosphate method we transfected the pcGRA4 into CHO (Chinese hamster ovary) cells. The yielded protein was separated by SDS-PAGE and moved by electroblotting to nitrocellulose paper.

**Results:** Result of SDS-PAGE analysis showed the appearance of band approximately 42 kDa which was absent in the negative control, that was able to identify toxoplasmosis antibody IgM<sup>+</sup> serum in western blot analysis.

**Conclusion:** pcGRA4 plasmid is able to synthesis of antigenic protein in CHO cells. The ability of pcGRA4 for induction of protective immune response against toxoplasmosis will be evaluated in mouse model.

### Introduction

*Toxoplasma gondii* is apicomplexan parasite with a worldwide distribution that can cause toxoplasmosis infection (1). In immunocompromised hosts such

as AIDS patients, the infection is severe. Primary acquired infection during pregnancy can be transmitted to the fetus and can produce severe symptoms such as miscarriage, neuro-

logical damage, ocular complications and other defects (2).

Consumption of food contaminated with tissue cysts or ingestion of oocysts released in the feces of infected cats can transmit this infection to human (3). Although drugs for treatment of toxoplasmosis infection in the acute phase are the main strategy, drug-resistance and side effect is seen, and they do not have effect on the chronic phase of infection (4). Protection against infection is mediated by T cell and involves both CD4+ and CD8+ Tcells (5).

The only industrial vaccine is, attenuated tachyzoite S48 strain famous as Toxovax (6). Which has short shelf-life, unwanted effects and high cost (7). Therefore, a new and affordable recombinant vaccine which stimulates T-cell-mediated protective immunity is needed.

In both infections acute and chronic phase excreted/secreted antigens (ESA) of *T. gondii* play main function in the stimulation of the host immune system (8). GRA proteins localized in both the PV and the cyst wall, several GRA gene expression demonstrate that GRA proteins are important for maturation of PV and transformation into a cyst (9, 10).

One of dense granule antigen is GRA4 that secrete from tachyzoite and bradyzoite, GRA4 genome is unique without intron (11). Oral infection with *T. gondii* induces both humoral and cellular immune responses by GRA4 peptides because amino acids 229-242 and 231-245 are epitopes for B and T-cell (12, 13). Many researchers candidate the GRA4 for vaccine and immunization against *T. gondii*.

The effect of plasmid containing SAG and GRA4 genes was studied with and without plasmid GM-CSF. The first one increases toxoplasmosis resistance, while the second one has higher protective effect (14). Martin et al. focused on the GRA4 recombinant proteins and ROP2 *T. gondii* along with alum in mice C57BL/6 and C3H. GRA4 and GRA4-ROP2 plasmids revealed similar levels of IgG isotypes against GRA4, but immunization with both plasmids caused higher level of IgG1

against ROP2 (15). Zhang et al. combined recombinant expression plasmids and vaccinia virus both of which contained GRA4, and injected the mice. The mice with lethal doses of *T. gondii* challenge remained alive. Cysts formation was blocked in mice immunized by the primary regime and heterologous reinforce (16).

In this article, we explain the expression of *T. gondii* GRA4 gene by pcGRA4 in CHO cells and confirm it by SDS-PAGE and Western blot analyses.

## Materials and Methods

### *Confirming the GRA4 cloning in pcGRA4 recombinant expression plasmid with KpnI and EcoRI enzymes*

We firstly extracted pcDNA3 and pcGRA4 plasmids existed in the transformed bacteria, grown in LB medium containing ampicillin (17). The extraction was performed using the plasmid extraction kit (made by Roch Germany Company). Simultaneous application of the two enzymes has been used for enzyme cutting in double digestion way, and the recombinant plasmid was cut concurrent with the expression plasmid pcDNA3 (as a control sample) using KpnI and EcoRI. According to the Fermentas company kit instruction, the enzyme reaction to the volume of 20 mL were placed at 37° C overnight after vortex and spine (it contained 5 mL pcGRA4 recombinant plasmid, 1 unit EcoRI enzyme, 1 unit KpnI enzyme, 2 mL tango buffer and 11 mL distilled water). The result of the enzyme cut along with a molecular weight marker was electrophoresed on agarose gel.

### *GRA4 gene PCR by using pcGRA4 recombinant plasmid as a template*

With using specific primers, we determine presence of the GRA4 gene in expression plasmid and separate the recombinant plasmid from other plasmids (18).

The forward and reverse primers were designed according to the nucleotide sequence in

Gene Bank database  
(<https://www.ncbi.nlm.nih.gov/genbank/>)  
with accession No. EU660037 and 1058 bp  
and Gen Runner Software. The specific primers  
were as follows:

Forward primer: 5'-  
CGCGGGTACCATGCAGGG-CACTTGGTTTTTC-3'  
Reverse primer: 5'-  
CGCGGAATTCCTCACTCTTTGCG-CATTCTTT-3'  
EcoRI: GAATTC  
KpnI: GGTACC

PCR reaction to the volume of 25 mL was  
performed:

10 × PCR buffer 2/5 μl, 50mM MgCl<sub>2</sub> 0/75  
μl, 10mM dNTP 0/5 μl, 10 Pomol/μl primer  
forward 1 μl, 10Pmol/μl primer Reverse  
1 μl, (5u/μl) Taq DNA Polymerase 0/5 μl, Ex-  
tracted DNA 3 μl, ddH<sub>2</sub>O 15/75 μl. The above  
materials were placed on a vial 0. 5ml, after  
vortex and spine. Then, they were placed in  
thermocycler and PCR was conducted based  
on the following plan: denaturation 60 sec at  
94°C, annealing 30 sec at 60°C, extension 1  
min at 72°C. These processes were repeated  
for 30 cycles and the PCR product was loaded  
on agarose gel and electrophoresed (18).

#### *Transfection of pcGRA4 recombinant plasmid into the CHO eukaryotic cells*

CHO cells were used as pcGRA4 recombi-  
nant plasmid host to express GRA4 gene pro-  
tein. Eukaryotic cell was cultured in flasks of  
75 ml at 37 °C and 5% CO<sub>2</sub>. For each 100 ml  
DMEM medium, 10 ml of sterile FCS and 1  
ml combination of antibiotics (penicillin 100  
unit/ml, streptomycin 100 unit/ml) were add-  
ed. The number of 1-3×10<sup>6</sup> eukaryotic cells  
were cultured in each 35 mm well in six-cell  
plate. When the cells filled 50%-80% of the  
plate, transfection was performed using  
calcium phosphate method. Then, 100 mL of  
calcium chloride 2. 5 M has added to 25  
**μg/ml** DNA plasmid diluted at a ratio of  
1/10 with Tris-Hcl buffer. The volume was  
reached to 1ml using distilled water. One vol-  
ume of this solution 2xCa/DNA was rapidly  
and suddenly added to the same volume of 2x  
HEPES solution (1. 5mm Na<sub>2</sub>HPO<sub>4</sub>, 140

mm NaCl, 50 mm HEPES, pH 7. 05 at 23 °C),  
then a slight smog appeared within a few sec-  
onds, which marks the formation of sediment.  
The solution was centrifuged in 30 sec and  
16000 gr round (at 0 °C) and quickly 250 mL  
of the above solution was removed, the light  
absorption was measured against a blank  
without DNA and phosphate at a wavelength  
of 320 nm. Measurement of the light absorp-  
tion is used to confirm DNA connection to  
the precipitate. For each 1 ml medium, 100 μl  
precipitate was added to plate containing the  
cell and the plates were incubated for 72 h.  
Then, a transfected well and a control well  
(plasmid without GRA4 gene) were collected  
in a completely sterilized condition. The cells  
were washed with sterilized PBS then 400 μl  
PBS was added to each well. The cells were  
separated from the plane's floor. For this pur-  
pose, the contents of each well were passed  
through sampler and collected in a vial of 1. 5  
ml to be kept at -20°C until the usage  
time (19).

#### *SDS PAGE and Western blot*

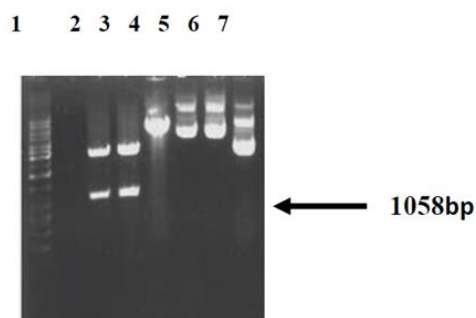
To confirm GRA4 gene expression in  
eukaryotic cell, we applied acrylamide gel 10%  
electrophoresis. Moreover, we used freeze and  
thaw method to break transfected and non-  
transfected cells. Four microliter antiprotease  
was added to vial (cell volume 0. 01) and the  
cells were frozen and thawed several times.  
Then, they were centrifuged for five minutes  
in 3000 rpm and the supernatant was exam-  
ined using SDS-PAGE and Western blot  
method. A volume of the sample buffer SDS-  
PAGE was mixed with five volume of the  
sample and boiled for five minutes. 50 μl of  
samples were placed in wells and the container  
was connected to the power supply (120 v)  
and transferred the protein bands of acryla-  
mide gel into a nitrocellulose paper, then  
blocking solution (1% BSA-PBST20) was  
added. And was kept at 4 °C overnight. Finally,  
paper was removed from blocking solution  
and put in human serum of patients with acute  
toxoplasmosis. It was added the peroxidase-

conjugated anti-human IgM (DAKO, Denmark) diluted in 1% BSA-PBST20 (1/200 and 1/2000, respectively). An appropriate volume of the DAB (DAKO, Denmark) was poured on the paper and a brown band appeared. The band's molecular weight was identified according to the protein marker. This band is not in non-transfected cells that confirmed the specific protein band.

## Results

### *The results of pcDNA3 expression plasmid enzyme cut and pcGRA4 recombinant plasmid*

The pcGRA4 recombinant and pcDNA3 expression plasmids were cut with EcoRI and KpnI enzymes. The resulted pcGRA4 recombinant enzyme plasmid which was cut (during concurrent enzyme cut reaction) with KpnI and EcoRI was electrophoresed and two bands with the weights of about 5.4 Kbps (weight of pcDNAs without band) and about 1058bp (weight of GRA4) appeared. GRA4 gene was cloned in this plasmid (Fig. 1).

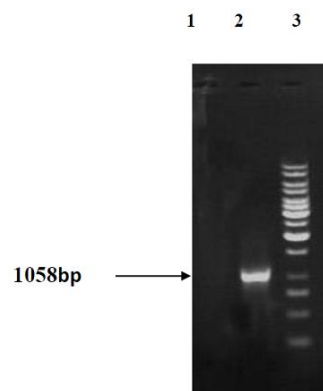


**Fig. 1:** Restriction enzyme (KpnI and EcoRI) analysis of recombinant plasmid pcDNA3 and pcGRA4. Lane 1: 1000 bpDNA ladder, Lanes 2-3: release of 1058 bp specific gene insert in pcGRA4, lane 4: pcDNA3, Lane 5- 6: pcGRA4 without cutting, Lane 7 pcDNA3 without cutting

### *Results of GRA4 PCR using pcGRA4 recombinant plasmid as a template*

Results of PCR product electrophoresis with pcGRA4 recombinant plasmid using specific primers revealed that GRA4 gene's 1058bp

band has been amplified from pcGRA4 recombinant plasmid and the GRA4 gene, while there was no band in electrophoresis of the pcDNA3 plasmid's PCR product. Therefore, cloning of GRA4 gene band in pcDNA3 plasmid was confirmed (Fig. 2).



**Fig. 2:** PCR amplification and gel electrophoresis. Lanes 1: pcDNA3, Lane 2: PCR product of pcGRA4 (approximately 1058 bp), Lane 3: 1000 bpDNA ladder

### *Results of pcGRA4 recombinant plasmid expression in CHO cells*

In order to investigate GRA4 gene protein expression, the CHO eukaryote cells were applied. After transfecting CHO cells with pcGRA4 recombinant plasmid and the plasmid without GRA4 gene as control were cultured 72 h, the protein was collected, and was analyzed using SDS-PAGE and Western blot methods.

### *Result of determining the proteins molecular weight using SDS-PAGE*

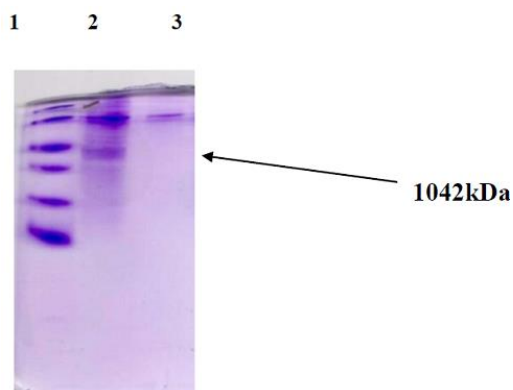
The results of SDS-PAGE has revealed that the band in the column related to the cell well transfected by pcGRA4 plasmid have been observed in the weight area of about 42 kDa, while they are not in pcDNA3 plasmid column (Fig. 3).

### *Result of Western blot*

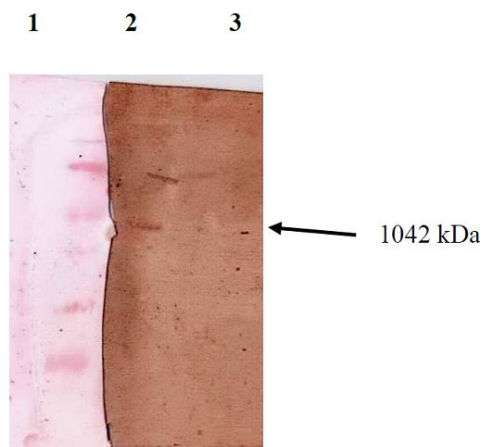
The nitrocellulose paper on which the separated proteins are transferred from the SDS-



PAGE gel, the molecular weight of protein band is about 42 kDa in the well transfected by pcGRA4 plasmid while there is no band in the control well. Formation of this band on the nitrocellulose paper shows that GRA4 protein is identified by IgM<sup>+</sup> human anti toxoplasma serum (Fig. 4).



**Fig. 3:** SDS-PAGE analysis on the expression of recombinant GRA4 in CHO cell. Lane 1: protein molecular weight marker (top to down 116, 66, 2, 45, 35, 25, 18, 4, 14, 4 kDa), Lane 2: contained supernatant of CHO cells transfected, Lane 3: supernatant of untransfected CHO cells



**Fig. 4:** Western blotting showed human *T. gondii* positive sera recognizing GRA4 protein from transfected CHO cells. It was not detected in non-transfected control cells. Lane 1: protein molecular weight marker (top to down 116, 66, 2, 45, 35, 25, 18, 4, 14, 4 kDa), Lane 2: containing pcGRA4 plasmid with band at about 42 kDa, Lane 3: pcDNA 3 (negative control)

## Discussion

Observing the protection fetus from congenital infection during pregnancy in women chronically infected with *T. gondii* indicate the degree of immunity against *T. gondii* and in immunocompetent individual first infection result in protective immune response against second infection, suggest that effective vaccine can confer protection against this infection and congenital transmission(20). DNA vaccines have ability to stimulate CD4<sup>+</sup> T-lymphocyte and CD8<sup>+</sup> cytotoxic T-lymphocyte (CTL) responses against the antigen insert to expression plasmid (21). Oral infection with *T. gondii* induce humoral and cell-mediate immune responses by GRA4 peptides because amino acids 229-242 and 231-245 are epitopes for B and T-cell (16,17). Amino acids 229-242 from GRA4 induces noticeable proliferation of primed-CBA/J mice T lymphocytes (22). Serum IgG antibodies from infected sheep and humans, and IgA antibodies of milk and intestinal from infected mice recognized with Protein C (amino acids 297-345) of GRA4 gene (23).

At first to for building a recombinant vaccine, we have to confirm the expression of GRA4 gene of *T. gondii* in eukaryotic cells (CHO). GRA4 gene cloning in pcDNA3 plasmid was confirmed using restriction enzyme and PCR methods. Then GRA4 gene expression was examined in vitro. Firstly, pcGRA4 recombinant plasmid was transfected in CHO eukaryote cells, using calcium phosphate method and with SDS-PAGE and Western blot analyze the protein band with the molecular weight of about 42 kDa was distinguished. It was active because it could be recognized by human antibody positive serum from patient with acute toxoplasmosis infection. pET-32a expression vector was used to GRA4 gene expression in prokaryotic system and reported the gene's molecular weight of about 50 kDa. The difference in the molecular

weight is related to the histidine-tagged application (24). HEK293T eukaryotic cell was used to gene expression and found that the molecular weight was about 70 kDa, which composed of 40 kDa and 30 kDa weights of GRA4 gene expression and green fluorescent protein producer, respectively (25).

GRA4 gene was cloned into pPICZ $\alpha$  A expression vector then integrated into the *Pichia Pastoris* genome according to the manufacturer's procedure of the Easy Select™ *Pichia* Expression kit. The antigen expressed together with the pre-sequence of the  $\alpha$ -factor of yeast. SDS-PAGE analysis confirmed that the recombinant protein expressed as a 40 kDa molecular weight. The antigenic reactivity found in the Western blot analysis (26).

Calcium phosphate transfection method was used based on Protection mammalian transfection system (Promega kit). Although they use Cos-7 cells for eukaryotic expression cell, the specific band with a molecular weight of about 40 kDa were observed in western blot (15). GRA4 gene was cloned in pcDNA3 to produce recombinant eukaryotic expression vector pcGRA4. Then performed transfection of pcGRA4 in Cos-7 eukaryotic cells by using Lipofectamine method. The protein obtained was 40-41 kDa molecular weight and was in the highest immunostimulatory effect (27). Therefore finding in this study approximate close to molecular weight of GRA4 protein expression in other studies. Calcium phosphate transfection is the method of choice to produce long-term stable transfectants. This method also works well for transient expression of transfected genes and can be used with most adherent cell lines.

## Conclusion

GRA4 gene that previous subcloned into pcDNA3 an expression plasmid can express protein in eukaryotic CHO cell. We will use from expression GRA4 plasmid to construct recombinant vaccines and evaluated the ability

of pcGRA4 for protective immune response against toxoplasmosis in mouse models.

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## Conflict of Interest

The authors declare that there is no conflict of interests.

## References

1. Dubey JP. The history and lifecycle of *Toxoplasma gondii*. In: Weiss LM, Kim K, editors. *Toxoplasma gondii*, the model apicomplexan: perspectives and methods. London, UK: Academic Press; 2007. p: 1–17.
2. Kravetz JD, Federman DG. Prevention of toxoplasmosis in pregnancy: knowledge of risk factors. *Infect Dis Obstet Gynecol*. 2005; 13(3): 161-5.
3. Kijlstra A, Jongert E. Control of the risk of human toxoplasmosis transmitted by meat. *Int J Parasitol*. 2008;38(12): 1359-70.
4. Meerburg BG, Van Riel JW, Cornelissen JB et al. Cats and goat whey associated with *Toxoplasma gondii* infection in pigs. *Vector Borne Zoonotic Dis*. 2006;6(3): 266-74.
5. Suzuki Y, Orellana MA, Schreiber RD, Remington JS. Interferon-gamma: the major mediator of resistance against *Toxoplasma gondii*. *Science*. 1988;240(4851): 516-8.
6. Buxton D. Toxoplasmosis. In: *Diseases of Sheep*. 2nd edition. Ed. W. B. Martin and I. D. Aitken. pp. 49-58. Blackwell Scientific Publications, Oxford. (1991).
7. Mévélec MN, Ducournau C, Bassuny Ismael A et al. Mic1-3 Knockout *Toxoplasma gondii* is a good candidate for a vaccine against *T. gondii*-induced abortion in sheep. *Vet Res*. 2010;41(4): 49.
8. Son ES, Nam HW. Detection and characterization of excretory/secretory proteins from *Toxo-*

- plasma gondii* by monoclonal antibodies. Korean J Parasitol. 2001; 39(1): 49–56.
9. Mercier C, Adjogble KD, Daubener W, Delaun MF. Dense granules: are they key organelles to help understand the parasitophorous vacuole of all apicomplexa parasites? Int J Parasitol. 2005; 35(8): 829-849.
  10. Cesbron-Delaun MF, Gendrin C, Travier L et al. Apicomplexa in mammalian cells: trafficking to the parasitophorous vacuole. Traffic. 2008; 9: 657–664.
  11. Cornelissen AWCA, Overdulve JP, Ploeg MVD. Determination of nuclear DNA of five eucoccidian parasites, *Isospora* (*Toxoplasma*) *gondii*, *Sarcocystis cruzi*, *Eimeria tenella*, *E. acervulina* and *Plasmodium berghei*, with special reference to gamontogenesis and meiosis in *I. (T.) gondii*. Parasitology. 1984; 88: 531-553.
  12. Chardes T, Bourguin I, Mevelec MN et al. Antibody responses to *Toxoplasma gondii* in sera, intestinal secretions, and milk from orally infected mice and characterization of target antigens. Infect Immun. 1990; 58(5): 1240–1246.
  13. Meisel R, Stachelhaus S, Mevelec MN et al. Identification of two alleles in the GRA4 locus of *Toxoplasma gondii* determining a differential epitope which allows discrimination of type I versus type II and III strains. Mol Biochem Parasitol. 1996; 81(2): 259–263.
  14. Mevelec M, Bout D, Desolme B et al. Evaluation of protective effect of DNA vaccination with genes encoding antigen GRA4 and SAG1 associated with GM-CSF plasmid antigen acute, chronic and congenital Toxoplasmosis in mice. Vaccine. 2005; 23: 4489-4499.
  15. Martin V, Supanitsky A, Echeverria PC et al. Recombinant GRA4 or ROP2 protein combined with alum or the GRA4 gene provides partial protection in chronic murine models of Toxoplasmosis. Clin Diagn Lab Immunol. 2004; 11(4): 704-710.
  16. Zhang G, Huang VT, Battur B. A heterologous prime-boost vaccination regime using DNA and a vaccinia virus, both expressing GRA4, induced protective immunity against *Toxoplasma gondii* infection in mice. Parasitology. 2007; 134(10): 1339-1346.
  17. Sambrook J, Fritsch EF, Maniatis T. *Molecular cloning: A laboratory manual*, Second Edition. Plainview: Cold Spring Harbor Laboratory Press. 1989.
  18. Masebi N, Ghafarifar F, Sharifi Z et al. Cloning and Characterization of GRA4 gene of *Toxoplasma gondii* (RH strain) in expression eukaryotic vector pcDNA3. Daneshvar. 2010; 17(85): 1-8.
  19. Martin J, Annette Schallhorn M, F M Wurm. Transfecting mammalian cells: optimization of critical parameters affecting calcium-phosphate precipitate formation. Nucleic Acids Res. 1996; 24(4): 596-601.
  20. Liu Q, Singla LD, Zhou H. Vaccines against *Toxoplasma gondii*: status, challenges and future directions. Hum Vaccin Immunother. 2012; 8(9): 1305–1308.
  21. Jongert E, Roberts C W, Gargano N et al. Vaccines against *Toxoplasma gondii*: challenges and opportunities. Mem Inst Oswaldo Cruz. 2009; 104(2): 252-266.
  22. Chardes T, Velge-Roussel F, Mevelec P et al. Mucosal and systemic cellular immune responses induced by *Toxoplasma gondii* antigens in cyst orally infected mice. Immunology. 1993; 78: 421-429.
  23. Ho-Woo Nam. GRA Proteins of *Toxoplasma gondii*. Maintenance of Host-Parasite Interactions across the Parasitophorous Vacuolar Membrane. Korean J Parasitol. 2009; 47: S29-S37.
  24. Ram H, Rao JR, Tewari AK et al. Molecular cloning, sequencing, and biological characterization of GRA4 gene of *Toxoplasma gondii*. Parasitol Res. 2013; 112: 2487–2494.
  25. Min Meng, Aihua Z, Gang Lu et al. DNA prime and peptide boost immunization protocol encoding the *Toxoplasma gondii* GRA4 induces strong protective immunity in BALB/c mice. BMC Infect Dis. 2013; 13: 494.
  26. Lau YL, Hasan MT, Thiruvengadam G et al. Cloning and expression of *Toxoplasma gondii* dense granular protein 4 (GRA4) in *Pichia pastoris*. Trop Biomed. 2010; 27(3): 525–533.
  27. Desolme B, Mevelec MN, Buzoni-Gatel D, Bout D. Induction of protective immunity against Toxoplasmosis in mice by DNA immunization with a plasmid encoding *Toxoplasma gondii* GRA4 gene. Vaccine. 2000; 18: 2512-2521.