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C-type Lectin Protein mosGCTL-2 From *Aedes aegypti* is a Novel Factor for Dengue Virus Infection*

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Abstract C-type lectins (CTLs) are a family of carbohydrate-binding proteins that share a common structural motif; they are quite conserved evolutionarily from arthropods to mammals and play an essential role in immune responses. *Aedes aegypti* is a pivotal vector for the dengue virus and expresses more than 30 types of C-type lectins, which are critical for both viral and bacterial infections. A recent study indicates that mosGCTL-3 interacts with a dengue virus-2 envelope protein (DENV-2 E protein) in *vivo* and *in vitro* thereby enhancing the infection of *A. aegypti*. Here, in this report we found another C-type lectin protein, mosGCTL-2 with important functions similar to mosGCTL-3. Results from the phylogenetic tree analysis suggested that there is sequence similarity between mosGCTL-2 and mosGCTL-3, with 43.56% of their amino acid sequences being identical. We constructed *Drosophila* S2 cell expression system to purify mosGCTL-2. *In vitro* experiments showed that mosGCTL-2 binds to the DENV-2 E protein through a calcium-dependent manner. The upregulation of mosGCTL-2 was noted in *A. aegypti* and was important for dengue virus 2 (DENV-2) infection *in vivo*. These findings suggest that mosGCTL-2 may be a pattern recognition receptor that performs an important function in the infection of *A. aegypti* by the dengue virus.

Key words C-type lectin, *Aedes aegypti*, mosGCTL-2, DENV-2, envelope protein, calcium-dependent binding
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Dengue is an arthropod-borne viral disease caused by the four dengue virus serotypes (DENV 1-4), which are transmitted by *Aedes* mosquitoes. In the past few decades, dengue viruses have spread rapidly in countries and regions, leading to an increase in the frequency of epidemics and severe dengue cases. Dengue has evolved from a common contagious disease to a major public health problem[1]. C-type lectins (CTLs) are a group of carbohydrate-binding proteins. In the process of infection of mammals by dengue viruses, a C-type lectin binds to the virus and mediates viral infection[2]. C-type lectins are widely distributed among immune cells, such as dendritic cells and macrophages, and are involved in positive and negative regulation of the immune system[3-4]. In mammals, DC-SIGN (CD209) and L-SIGN (CD209L) are C-type lectin families; their members bind to dengue virus envelope protein (DENV E

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protein), thereby mediating viral invasion[5-7]. CLEC5A (C-type lectin domain family 5, member A) engages mannose receptor (MR) to mediate viral infection of macrophages and monocytes while promoting the development of dengue[8].

Aedes mosquitoes belong to the insect order *Diptera* (family Culicidae), which includes approximately 3 500 species worldwide. *Diptera* species are the intermediate host of various pathogens, such as infectious agents of dengue fever, malaria, yellow fever, filariasis, and Japanese encephalitis. There are mosquitoes distributed across all continents except Antarctica. Among mosquitoes, genera *Anopheles*, *Aedes*, and *Culex* have the largest populations. *Aedes spp.* can transmit dengue fever, yellow fever, and chikungunya fever. *Anopheles spp.* mainly spread malaria parasites (*Plasmodium spp*.), and *Culex spp.* are carriers of the encephalitis virus.

C-type lectins have more than 30 isoforms in *A. aegypti*, mostly in the form of secreted proteins. *A. aegypti* C-type lectin mosGCTL-3 is abundant in mosquito saliva and plays an essential role in viral transmission. The DENV-2 E protein of the virus is recognized by mosGCTL-3[9]. An *Aedes* mosquito C-type lectin binds to the West Nile virus envelope protein and binds to the secondary receptor tyrosine phosphatase receptor mosPTP-1 (mosquito protein tyrosine phosphatase -1), thereby promoting viral infection of cells[10]. In addition to its involvement in viral infection, mosquito C-type lectins also play an important part in bacterial infection. C-type lectin CTL4 (GenBank accession No. AGAP005335) and CTLMA2 (GenBank accession No. AGAP005334) are expressed by *Anopheles gambiae* and can inhibit bacterial infection[11]. MosGCTL-24 and mosGCTL-29 from *Aedes* mosquitoes can prevent antimicrobial peptides from binding to bacteria and are important for the colonization of mosquito intestines by bacteria[12].

MosGCTL-2 with an unknown function belongs to the C-type lectin family. The results of the phylogenetic tree analysis suggested that there is sequence similarity between mosGCTL-2 and mosGCTL-3, with 43.56% of their amino acid sequences being identical. In this study, we purified secreted mosGCTL-2 and conducted a preliminary analysis of its function. The results indicate that mosGCTL-2 may be a potentially crucial immune molecule in *A. aegypti*.

1 Materials and methods

1.1 Virus culture and infection

A. aegypti (Rockefeller strain) were kept in a low-temperature incubator with lighting, at a constant temperature of 26 ℃ and 80% relative humidity, in accordance with the standard method described in the literature[13].

C6/36 cells derived from *Aedes albopictus* were cultured at 30 ℃ in a 5% CO_2 incubator, in complete DMEM supplemented with 10% of fetal bovine serum (FBS) and 100 U/ml streptomycin and penicillin.

DENV-2 was inoculated into C6/36 cells, at a ratio of 0.1% and cultured for 4−6 days. The culture supernatant was collected from the cytopathic lesions and stored at −80 ℃ for later use.

Ten MID_{50} of DENV-2 was injected into female mosquitoes via the thorax. After 12 h of infection, the mosquitoes were collected and killed. Total RNA was extracted, reverse transcribed into cDNA, and probed for *mosGCTL-2* mRNA abundance by means of SYBR Green quantitative polymerase chain reaction (qPCR).

1.2 cDNA synthesis

A. aegypti specimens were homogenized in 400 μl of buffer I with a Pestle Grinder system (#03-392-106, Fisher Scientific®). After homogenization, 150 μl of buffer II was added, and the suspension was vortexed for 15−30 s, and centrifuged 12 000 *g* and 4℃, for 5 min. The supernatant was transferred to a 1.5 ml tube, to which 250 μl of isopropanol was added followed by mixing. Total RNA was isolated according to the instructions for the AxyPrep® Multisource Total RNA Miniprep Kit (AP-MN-MS-RNA-250, Axygen®) and was eluted with RNase-free water. Total RNA was isolated from homogenized mosquitoes and was reverse-transcribed into complementary DNA (cDNA) using the iScript® cDNA Synthesis Kit (170-8890, Bio-Rad®).

1.3 Construction of the mosGCTL−2 expression vector

The *mosGCTL-2* gene (GenBank accession No. AAEL000533) was amplified from the cDNA of *A. aegypti* (the Rockefeller strain) with forward primer (5'-AGAGGAGATCTCATCACCATCACCATCACG-ATTACGATATCCCAACGACCGAAAACCTGTATT-TTCAGGGCCAGCAGACATGCGACAACGAC-3') and reverse primer (5'-AGAGGTCTAGA

TTACGCCTGTTCGCACACAAAGC-3'), digested with *Bgl* II and *Xba* I, and ligated (T4 -Ligase, New England BioLabs) into the *pMT/BiP/V5-His A* expression vector (V4130-20; Invitrogen®) containing a *Drosophila* secretion signal. The new plasmid was transfected into *Escherichia coli* DH5α cells, and the transfected cells were spread on plates containing ampicillin (100 mg/L). DNA from ampicillin-resistant clones was analyzed by *Bgl* II/*Xba* I restriction digestion and by PCR to confirm the presence of the insert. The isolated plasmid was validated by DNA sequencing.

1.4 Expression and purification of mosGCTL−2

Schneiders *Drosophila* Medium (11720-034, Thermo Fisher® Scientific) containing 10% of heat-inactivated FBS was used for the selection of a stable cell line. The expression vector and *pCoHygro* (selection vector) were transfected at a ratio of 19∶1 (*w*/*w*) into S2 cells, using the Effectene® Transfection Reagent (301425, Qiagen®). A selection medium containing 300 mg/L hygromycin B was added in place of the old one at 48 h post-transfection. Selection generally took 3 to 4 weeks. The stable cell lines were amplified in 75 cm^2 flasks and then transferred into spinner flasks for protein expression in a serum-free medium (10486025; Gibco®). After 3 days, 500 mmol/L copper sulfate was added to the medium. We continued to culture the cells for 4 days and collected the supernatant. The Millipore Labscale® TFF System was employed to replace the supernatant with buffer A (20 mmol/L Tris-HCl, 300 mmol/L NaCl, 1 mmol/L $CaCl_2$, pH 8.0).

The removed supernatant was loaded onto a HisTrap HP affinity chromatography column (17-5248-01, GE Healthcare), and buffer A was used to wash the column until no protein was detected in the flow through. Protein was next eluted with buffer A or buffer B containing increasing concentrations of imidazole (10, 50, 100, 300 mmol/L). Subsequent purification was performed using the AKTA system. The sample was purified on a size exclusion column (Superdex® 75 10/300 GL column, or Superdex® 200 Increase 10/300 GL column; GE Healthcare) with buffer A. Ultraviolet-spectrum absorption was monitored at 280 nm, and fractions containing protein were analyzed by means of a 420% ExpressPlus™ PAGE gel (M42012C, Genscript®). 8 mg mosGCTL-2 protein could be yield per liter cells.

1.5 Western blotting

Western blot analysis was performed to identify mosGCTL-2 protein of interest. The proteins were separated in 4% − 20% ExpressPlus™ PAGE gels (M42012C, Genscript®), and were then transferred to polyvinylidene difluoride membranes (IPVH00010, Millipore). The membranes were blocked with a solution containing 5% skim milk at 25℃ for 1 h, followed by incubation with a mouse anti-His antibody (HRP-66005, Proteintech®, 1∶2 000 dilution in a solution containing 5% skim milk [dry basis]) at 25℃ for 2 h. After 3-time washes with PBST for 15 min, finally, the signals on the membrane were visualized using the Enhanced Chemiluminescence Kit (1705060, Bio-Rad®).

1.6 Coimmunoprecipitation

Purified mosGCTL-2 and the supernatant of S2 cells expressing the DENV-2 E protein (the plasmid was kindly provided by the laboratory of Cheng Gong, Tsinghua University, E protein carrying a FLAG-tag) were incubated at 4℃ for 4 h. A rabbit anti-FLAG antibody (14793S, Cell signaling Technology®) was added to the solution and incubated for 2 h at 4℃. Finally, Pierce™ Protein A/G Agarose (20421, Thermo Fisher®) was added to the solution, followed by incubation at 4℃ for 1 h. The beads were washed with lysis buffer three times and collected by centrifugation at 4℃, and 500 *g* for 5 min, to remove nonspecifically bound proteins. The protein was then analyzed by Western blotting with a mouse anti-His antibody (HRP-66005, Proteintech®).

1.7 qPCR

A. aegypti specimens injected with DENV-2 or PBS were homogenized using buffer I from the AxyPrep® Multisource Total RNA Miniprep Kit (AP-MN-MS-RNA-250, Axygen®) and a Pestle Grinder system (#03-392-106, Fisher Scientific®). The detailed procedure for total RNA isolation is described in the AxyPrep® Multisource Total RNA Miniprep Kit manual. Total RNA was isolated from homogenized mosquitoes and was reverse-transcribed into complementary DNA (cDNA) using the iScript® cDNA Synthesis Kit (170-8890, Bio-Rad®). MosGCTL-2 mRNA was quantified by qPCR amplification with SYBR green. The primers for this analysis were as follows: 5'ATGGCTCTTTCATT-ATATCT3', and 5'CACAACATTTGGGAAGCAG-AA3'. The signal was normalized to actin from *A.*

aegypti, and the actin-specific primers were 5'GAACACCCAGTCCTGCTGACA3', 5'TGCGTCATCTTCTCACGGTTAG3'.

2 Results

2.1 Analysis of genes homologous to *A. aegypti* mosGCTL−3

MosGCTL-3 interacts with a dengue virus-2 envelope protein (DENV-2 E protein) *in vivo* and *in vitro* thereby enhancing the infection of *A. aegypti*[9]. We selected 32 *A. aegypti* C-type lectin protein sequences for analysis and found five proteins that were highly homologous to mosGCTL-3 (GenBank accession No. AAEL000535), namely, GenBank accession numbers AAEL009209, AAEL011079, AAEL005641, AAEL000533, and AAEL006456 (Figure 1a). Then, we analyzed the identity of the five proteins and compared them to mosGCTL-3. We found that the mosGCTL-2 protein (GenBank accession No. AAEL000533) was similar to mosGCTL-3 (Figure 1b).

The mosGCTL-2 protein contains a CLECT domain, which is a C-type lectin (CTL) or a carbohydrate-recognition domain (CRD). Many of these domains function as calcium-dependent carbohydrate binding modules. MosGCTL-2 protein was similar to mosGCTL-3, which would allow us to infer the protein's function.

2.2 Cloning of the *mosGCTL−2* gene and purification of the mosGCTL−2 protein

The *mosGCTL-2* gene of *A. aegypti* was obtained from *A. aegypti* cDNA with forward and reverse primers. The *mosGCTL-2* gene without signal sequences (final length, 470 bp) was thus obtained (Figure 2a). A His-tag was added to the N -terminus of the protein for convenient purification, and a stop codon was added at the end of the DNA fragment. This *mosGCTL-2* gene fragment was cloned into the multiple cloning site between *Bgl*II and *Xba*I sites of the *pMT/BiP/V5-His A* vector.

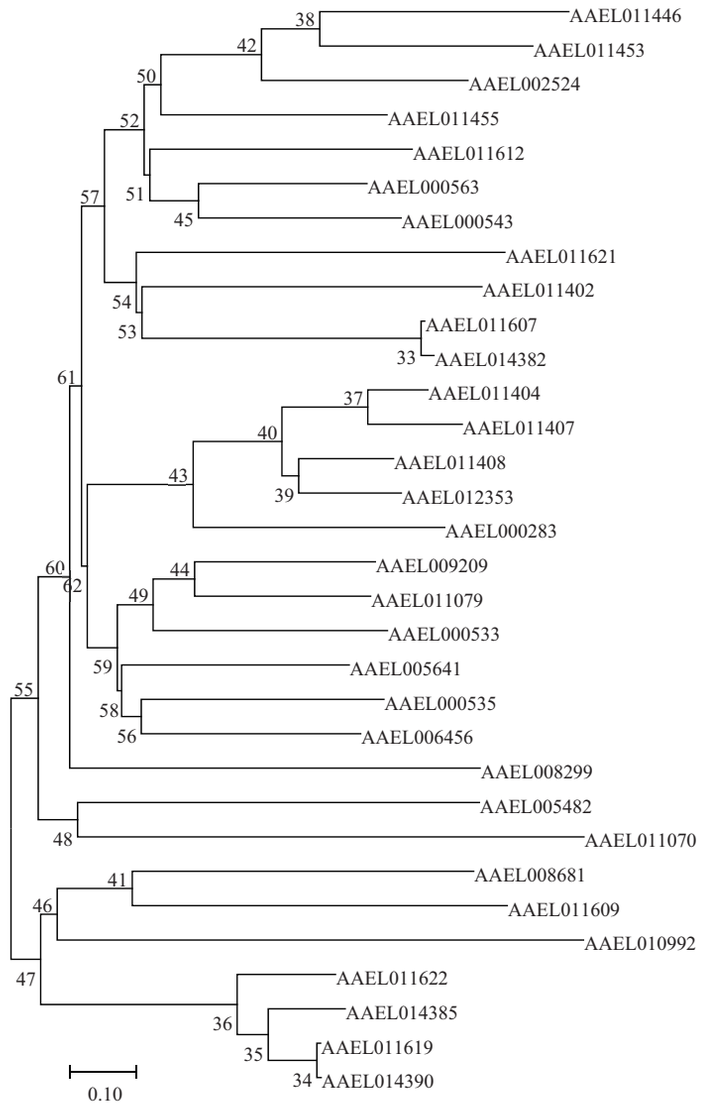
The mosGCTL-2 protein was expressed in the *Drosophila* S2 cell expression system. Vector *pMT/BiP/V5-His A* contains a *Drosophila* secretion signal. Twenty-four hours after cell transfection, 500 μmol/L of copper sulfate was added to the medium, and the cells were cultured for an additional 36 h. The mosGCTL-2 protein in the cell lysate and culture supernatant was detected by Western blot analysis (Figure 2b), and the size of the mosGCTL-2 protein was determined: ~18 ku.

Stable cell lines were selected with 300 mg/L hygromycin B for 3 or 4 weeks and were amplified in spinner flasks containing the Express Five® SFM (1×) medium (10486025; Gibco®). After incubation for 3 days at 28℃, 500 μmol/L copper sulfate was added to the medium, and the cells were cultured for another 4 days. The Millipore Labscale® TFF System was used to replace the supernatant with buffer A (20 mmol/L Tris-HCl, 300 mmol/L NaCl, 1 mmol/L $CaCl_2$, pH 8.0). The removed supernatant was loaded onto a HisTrap® HP affinity chromatography column. The protein was eluted with elution buffer (20 mmol/L Tris-HCl, 300 mmol/L NaCl, 1 mmol/L $CaCl_2$, 100 mmol/L imidazole, pH 8.0; Figure 2c). The Superdex-200 Increase 10/300 GL column was used to purify the mosGCTL-2 protein in the buffer (20 mmol/L Tris-HCl, 300 mmol/L NaCl, 1 mmol/L $CaCl_2$, pH 8.0). A major peak was observed at the elution volume of 16.5 ml (Figure 2d). A fraction of the effluent protein was collected every 500 μl. The protein collected in each tube was found to be mosGCTL-2 by electrophoresis in the 4% − 20% ExpressPlus™ PAGE gel (Figure 2e).

2.3 MosGCTL−2 interacts with the DENV−2 E（envelope）protein

MosGCTL-3 promotes DENV-2 infection of *A. aegypti* and interacts with the DENV-2 E protein[9]. We hypothesized that the mosGCTL-2 protein, which has a sequence similar to that of mosGCTL-3, may also have a similar function. Therefore, we detected the interaction between mosGCTL-2 and the DENV-2 E protein by coimmunoprecipitation. We used purified mosGCTL-2 protein and intracellular transiently expressed DENV-2 E protein for detection. The protein complex was pulled down by an anti-FLAG rabbit antibody and probed by an anti-His mouse antibody. EDTA is a calcium ion chelating agent, can prevent mosGCTL-2 and DENV-2 E interaction. As shown in Figure 3a, mosGCTL-2 bound to the DENV-2 E protein, and this interaction manifested calcium-dependence.

(a)



(b)

Gene No.	Name	Length(AA)	Query cover/%	Identity/%
AAEL009209	C-type lectin	162	86	39.62
AAEL011079	C-type lectin	160	87	40.74
AAEL005641	C-type lectin	162	86	41.35
AAEL000533	C-type lectin	154	84	43.56
AAEL006456	C-type lectin	147	84	43.14

Fig. 1　Bioinformatics analysis mosGCTL−3

（a）An unrooted phylogenetic tree of mosGCTL-3. The tree was constructed by the neighbor-joining method based on the alignment of mosGCTL-3 sequences. The bootstrap values of 5 000 are indicated on the branch nodes. （b）The percentages of amino acid identity for mosGCTL-3 were compared with other C-type lectin proteins of *A. aegypti*.

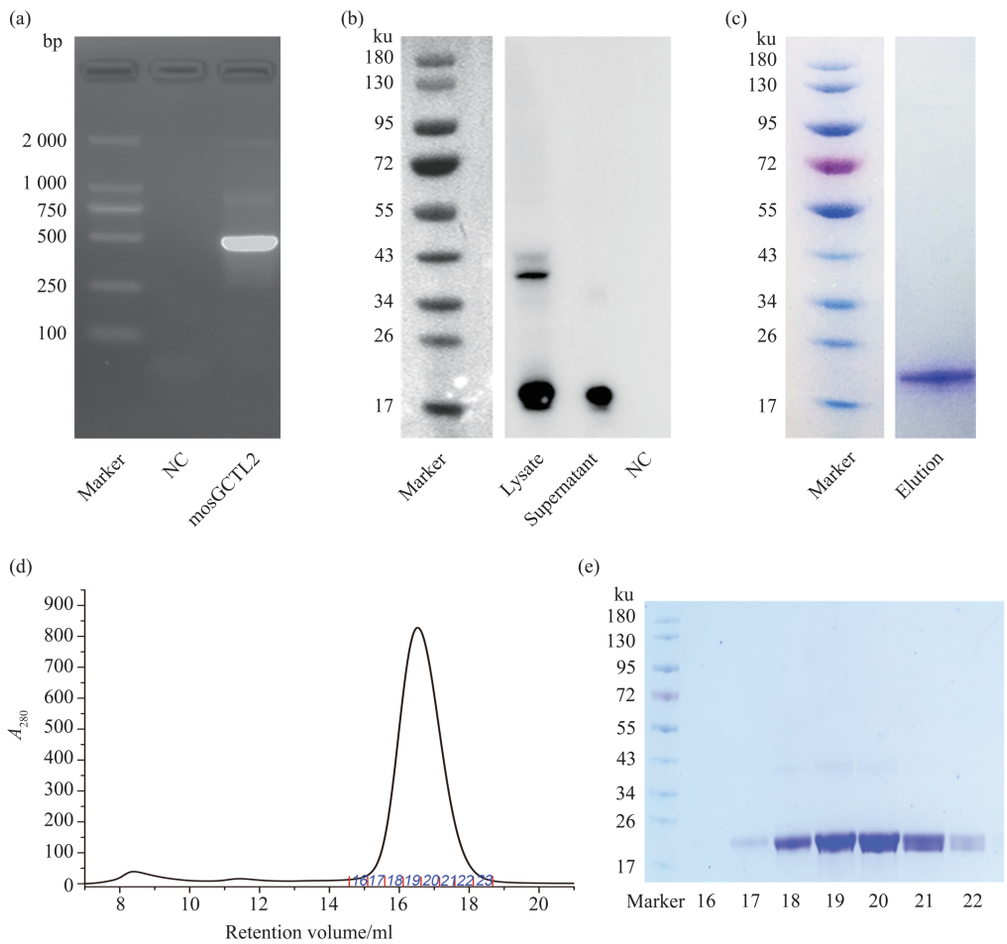


Fig. 2　Cloning of the *mosGCTL−2* gene and purification of the mosGCTL−2 protein

（a）Products of PCR amplification of the *mosGCTL-2* gene. The markers are shown as the DL2000 DNA ladder. Lane NC：PCR using water as the template. Lane *mosGCTL-2*： *mosGCTL-2* gene amplified from cDNA as the template， which was synthesized from the total RNA of *A. aegypti* by reverse transcription.（b）Western blot analysis of mosGCTL-2 expression in S2 cells. MosGCTL-2 protein expression was detected in both cell lysates and cell culture supernatants. NC is the culture supernatant of S2 cells.（c）Affinity column purification of the mosGCTL-2 protein. The mosGCTL-2 protein was eluted in the presence of 100 mmol/L imidazole.（d）The Superdex-200 Increase 10/300 GL column was employed to purify the mosGCTL-2 protein. The major peak elution volume for the mosGCTL-2 protein was ~16.5 ml.（e）A fraction of the effluent protein was collected every 500 μl. SDS-PAGE analysis of the mosGCTL-2 protein eluted from each tube in the main peak.

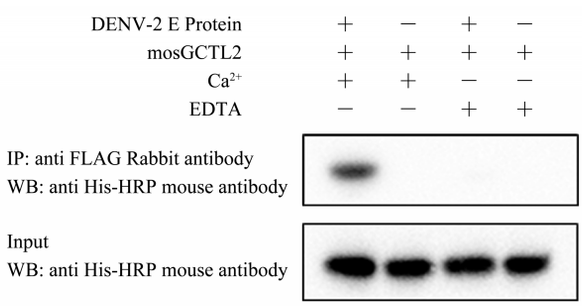


Fig. 3　MosGCTL−2 interacts with DENV−2 E protein

MosGCTL-2 interacted with the DENV-2 E protein，as detected by coimmunoprecipitation. The protein complex was pulled down by an anti-FLAG rabbit antibody and probed with an anti-His（horseradish peroxidase-conjugated，HRP）mouse antibody. At a calcium ion concentration of 5 mmol/L，the interaction between mosGCTL-2 and DENV-2 E is detected. 5 mmol/L EDTA can prevent mosGCTL-2 and DENV-2 E interaction.

2.4 The effect of DENV−2 infection on the expression of mosGCTL−2

Mosquitoes in the wild have evolved many immune mechanisms to deal with viral infections. Expression of C-type lectin proteins can be induced when mosquitoes are infected with viruses[9-10,14]. Here, we examined the expression of the mosGCTL-2 gene after *A. aegypti* was infected with DENV-2. It was found that mosGCTL-2 expression significantly increased in response to DENV-2 infection (Figure 4), suggesting that mosGCTL-2 may have an important effect during dengue virus infection of *A. aegypti*.

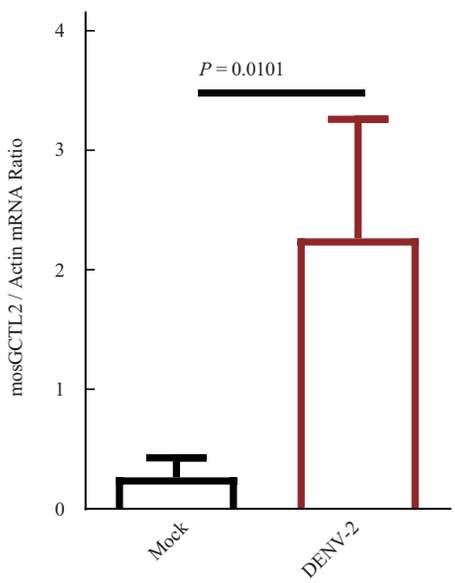


Fig. 4　DENV−2 infection increases the level of mosGCTL−2 mRNA

Ten MID_{50} of the DENV-2 virus was inoculated into each mosquito's thorax. After 12 h，mosquitoes were killed to determine the abundance of mosGCTL-2 mRNA by qPCR；the data were normalized to actin from *A. aegypti*. *MosGCTL-2* mRNA levels increased after DENV-2 infection. The data are expressed as the mean ± standard error.

3 Discussion

In terms of evolution, ~18 invariant residues are phylogenetically conserved in the main member of the C-type lectin family[13]. Several types of C-type lectins have been recognized as ligands that are exploited by arboviruses in a host and in a vector. Glycans on the surface of arboviruses, which are identified by a conserved motif in multiple C-type lectins, reinforce viral-infection pathogenesis[15-16]. MosGCTL-2 with an unknown function is a member of the C-type lectin protein family. To investigate the function of mosGCTL-2, the secreted mosGCTL-2 protein was expressed and purified by the molecular sieve technology. Most of C-type lectins are secreted. The signal peptide at the N-terminus of the mosGCTL-2 protein contains 20 amino acid residues. The secretion of the mosGCTL-2 protein was implemented *via* expression in the *Drosophila melanogaster* Schneider 2 (S2) cell eukaryotic system. The Labscale TFF (tangential flow filtration) System for buffer replacement is conducive to the subsequent affinity purification.

The C-type lectin family shares a common fold that comes into contact with a carbohydrate, and some folds do so in a calcium-dependent manner[17], and some act as receptors in pathogen recognition[4,18]. Dengue virus enters a host cell when the viral envelope glycoprotein, E, binds to a receptor and responds by conformational rearrangement to the reduced pH of an endosome. The conformational change induces the fusion of viral and host-cell membranes[19]. The previous study showed that proteins mosGCTL-3 and DENV-2 E interact with each other, and this interaction is calcium-dependent[9]. In agreement with the homology between mosGCTL-2 and mosGCTL-3 detected by phylogenetic tree analyses, we found that proteins mosGCTL-2 and DENV-2 E interacted also depends on calcium ions. We noted that the expression of mosGCTL-2 in mosquitoes significantly increased after infection with the dengue virus, suggesting that mosGCTL-2 is potentially an important immune molecule in *A. aegypti*. This result was consistent with the previously reported findings that the expression of C-type lectin mosGCTL-3 significantly increases during dengue virus infection of *A. aegypti*[9]. These results provide a basis for further research on the antiviral function of mosGCTL-2.

The C-type lectin superfamily contains a wide variety of proteins and plays an important part in the fight against viral infections, also is an important pattern-recognition receptor (PRR) in the innate immune system. C-type lectins not only associate with the DENV E protein but also bind to the West Nile virus E protein. As mammalian C-type lectins mentioned above, DC-SIGN (CD209) and L-SIGN (CD209L) are important cell attachment factors for

the invasion of immature dendritic cells by human immunodeficiency virus (HIV), dengue virus (DENV) and West Nile virus (WNV). As a C-type lectin, mannose receptor (MR) can directly bind to the E protein surface of the dengue virus and facilitates viral attachment to the cell surface, which further mediates viral infection of macrophages and monocytes[20]. C-type lectins attach to the secondary receptor tyrosine phosphatase receptor mosPTP-1 (mosquito protein tyrosine phosphatase -1), thereby promoting viral infection of cells[10]. Viral infection can stimulate the expression of a C-type lectin. MosGCTL-3 was induced with DENV-2 infection in *Aedes aegypti*, and the ability of *Aedes aegypti* to transmit DENV-2 was greatly reduced with mosGCTL3 suppression[9]. We found that mosGCTL-2 is likely to be a potential dengue virus pattern recognition receptor and is highly homologous to mosGCTL-3, maybe has similar functions. Therefore, this article provides a possibility to use mosGCTL-2 as a target molecule to design a specific transmission-blocking vaccine and thus to control the spread of the dengue virus.

The functions of the majority of C-type lectins are redundant[21]. Despite their crucial roles in the immune responses against pathogens and gut microbiome homeostasis[22], there are few studies on C-type lectins. Our study for the first time revealed that mosGCTL-2 engages in an interaction with the DENV-2 E protein. The latter protein is involved in cell adhesion, glycoprotein conversion, and pathogen recognition (e.g., *via* mosGCTL-2).

In conclusion, mosGCTL-2 and DENV-2 E protein interact with each other, and this interaction is calcium-dependent. Subsequent research efforts should focus on the interaction of proteins mosGCTL-2 and DENV-2 E *in vivo* to deepen our understanding of the involvement of C-type lectins in pathogen recognition.

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伊蚊C型凝集素mosGCTL–2是登革病毒感染相关的重要蛋白质*

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摘要　C型凝集素是一类含有糖结合结构域的蛋白质，从节肢动物到哺乳动物的C型凝集素都具有共同的基序，它在进化上相当保守，在免疫反应中发挥重要作用. 埃及伊蚊表达30多种C型凝集素蛋白，它是登革病毒的关键传播媒介，这些蛋白质对病毒和细菌感染均有至关重要的作用. 最近研究表明，C型凝集素mosGCTL-3与二型登革热病毒包膜蛋白具有相互作用，能够增强登革病毒对埃及伊蚊的感染. 在本文中，我们发现了C型凝集素蛋白mosGCTL-2具有与mosGCTL-3类似的功能. 两种C型凝集素mosGCTL-2和mosGCTL-3的氨基酸残基序列一致性高达43.56%. 为研究mosGCTL-2在登革病毒蚊媒传播中的作用，我们通过果蝇S2细胞表达系统表达纯化了mosGCTL-2蛋白. 结果表明，mosGCTL-2与二型登革热病毒包膜蛋白的结合具有钙离子依赖性. 进一步的研究表明，埃及伊蚊感染登革病毒能够诱导mosGCTL2表达上调，是二型登革热病毒感染埃及伊蚊所必需的蛋白质. 以上研究说明，mosGCTL-2蛋白可能是在登革热病毒感染埃及伊蚊中起重要作用的一种模式识别受体.

关键词　C型凝集素，埃及伊蚊，mosGCTL-2，二型登革病毒，包膜蛋白，钙依赖结合
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