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- (54) Benævnelse: **NY ANVENDELSE AF TRIAZOLO(4,5-D)PYRIMIDINDERIVATER TIL FOREBYGGELSE OG BEHANDLING AF BAKTERIEL INFEKTION**
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DESCRIPTION

[0001] The present invention relates to a new use of Triazolo(4,5-d)pyrimidine derivatives for prevention and treatment of bacterial infection.

[0002] Bacteria are often incriminated in healthcare-associated infections (including medical device-related infections), causing increased patient morbidity and mortality, and posing huge financial burden on healthcare services. The situation has become critical since more and more bacteria are becoming resistant to antibiotics belonging to various classes such as Penicillins, Methicillins, Carbapenems, Cephalosporins, Quinolones, Amino-glycosides, and Glycopeptides, and an increasing number of infections are becoming difficult to cure.

The increasing resistance to antibiotics is a growing public health concern because of the limited treatment options available for these serious infections. In Europe, antimicrobial resistance causes approximately 25,000 deaths every year. The clinical burden associated with antimicrobial resistance is estimated to cost approximately €1.5 billion per year.

At present, 700,000 deaths are estimated to be attributed to antimicrobial resistance globally as reported in Review on AMR, Antimicrobial resistance: Tackling a crisis for the health and wealth of nations, 2014

[0003] The use of antibiotics is not safe especially in long-term therapy or high dose therapy. Such environmental pressure may promote selection of resistant bacteria, population, altering population structure and increasing the risk of horizontal gene transfer leading to the mobility of resistant genes into the microbiome.

[0004] Antibiotic treatment targets both the « good » and the « bad » bacteria.

[0005] The human gastro-intestinal tract (GI) microbiota is made of about trillions of microorganisms most of them bacteria. Microbiota and host's defense relationship is essential for metabolic and physiological functions contributing to health. By disrupting this benefit interaction, dietary components, physical and psychological stress, drugs but also antibiotics increase incidence of several diseases like obesity, inflammation and cardiovascular diseases (CVD). CVD remain the first cause of death in industrial society with growing incidence in other countries.

[0006] For instance recent studies showed a direct link between long term antibiotics treatment, disruption of GI microbiota and risks of atherosclerosis in mice.

[0007] The source of bacterial infection is diverse and there is a large number of bacterial infections.

[0008] Infections caused by Gram-positive bacteria represent a major public health burden, not just in terms of morbidity and mortality, but also in terms of increased expenditure on patient management and implementation of infection control measures. *Staphylococcus*

aureus and *enterococci* are established pathogens in the hospital environment, and their frequent multidrug resistance complicates therapy.

[0009] *Staphylococcus aureus* is an important pathogen responsible for a broad range of clinical manifestations ranging from relatively benign skin infections to life-threatening conditions such as endocarditis and osteomyelitis. It is also a commensal bacterium (colonizing approximately 30 percent of the human population).

Two major shifts in *S. aureus* epidemiology have occurred since the 1990s: an epidemic of community-associated skin and soft tissue infections (largely driven by specific methicillin-resistant *S. aureus* [MRSA] strains), and an increase in the number of healthcare-associated infections (especially infective endocarditis and prosthetic device infections).

[0010] Coagulase-negative staphylococci (CoNS) are the most frequent constituent of the normal flora of the skin. These organisms are common contaminants in clinical specimens as well as increasingly recognized as agents of clinically significant infection, including bacteremia and endocarditis. Patients at particular risk for CoNS infection include those with prosthetic devices, pacemakers, intravascular catheters, and immunocompromised hosts.

Coagulase-negative staphylococci account for approximately one-third of bloodstream isolates in intensive care units, making these organisms the most common cause of nosocomial bloodstream infection.

Enterococcal species can cause a variety of infections, including urinary tract infections, bacteremia, endocarditis, and meningitis. Enterococci are relatively resistant to the killing effects of cell wall-active agents (penicillin, ampicillin, and vancomycin) and are impermeable to aminoglycosides.

Vancomycin-resistant enterococci (VRE) are an increasingly common and difficult-to-treat cause of hospital-acquired infection.

Multiple epidemics of VRE infection have been described in diverse hospital settings (e.g., medical and surgical intensive care units, and medical and pediatric wards) and, like methicillin-resistant *Staphylococcus aureus*, VRE is endemic in many large hospitals.

The beta-hemolytic *Streptococcus agalactiae* (Group B Streptococcus, GBS) is another Gram-positive bacteria. The bacteria can cause sepsis and/or meningitis in the newborn infants. It is also an important cause of morbidity and mortality in the elderly and in immuno-compromised adults. Complications of infection include sepsis, pneumonia, osteomyelitis, endocarditis, and urinary tract infections.

[0011] The factors that make these bacteria especially adept at surviving on various biomaterials include adherence and production of biofilm (see below).

The four above mentioned bacteria have the ability to form biofilms on any surface biotic and abiotic. The initial step of biofilm formation is the attachment/adherence to surface, which is stronger in shear stress conditions. The protein mainly responsible for this adhesion is the polysaccharide intercellular adhesin (PIA), which allows bacteria to bind to each other, as well as to surfaces, creating the biofilm. The second stage of biofilm formation is the development of a community structure and ecosystem, which gives rise to the mature biofilm. The final stage is the detachment from the surface with consequent spreading into other locations. In all the

phases of biofilm formation the quorum sensing (QS) system, mediating cell-to-cell communication, is involved.

[0012] Bacteria in the biofilm produce extracellular polymeric substances (EPS) consisting mainly of polysaccharides, nucleic acids (extracellular DNA) and proteins, that protect them from external threats, including immune system components and antimicrobials. Moreover, bacteria in the biofilm have a decreased metabolism, making them less susceptible to antibiotics; this is due to the fact that most antimicrobials require a certain degree of cellular activity in order to be effective. Another factor reinforcing such resistance is the impaired diffusion of the antibiotics throughout the biofilm because of the presence of the EPS matrix barrier.

[0013] It was also reported that in the biofilm there is higher rate of plasmid exchange increasing the chances of developing naturally occurring and antimicrobial-induced resistance.

[0014] Strategies that have been developed to eliminate biofilms target 3 different steps in the biofilm formation: inhibition of the initial stage, *i.e.* the adhesion of bacteria to surfaces; disrupting the biofilm architecture during the maturation process or step 2; inhibiting the QS system or step 3.

[0015] Because of the high resistance of these biofilms to antibiotics there is an increasing need of control and prevention of microbial growth and biofilm formation at step 2. The treatment in case of infected medical device is either a conservative treatment or the removal of the device together with a long treatment with antibiotics, but these approaches have high failure rates and elevated economical burden.

[0016] This is the reason why clinicians try to adopt a preventive approach by subadministering antibiotics before implantation. Another solution could be the modification of the medical devices, e.g. surfaces coated with silver, which have antimicrobial property or with hydrogels as well as polyurethanes, which reduce bacterial adhesion, to mention few examples.

[0017] According to Eggiman in American Society for Microbiology Press, Washington, DC 2000. p.247, pacemakers and implantable cardioverter-defibrillators [ICDs]) can become infected, with a rate of infections ranging from 0.8 to 5.7 percent.

[0018] The infection can involve subcutaneous pocket containing the device or the subcutaneous segment of the leads. Deeper infection can also occur that involves the transvenous portion of the lead, usually with associated bacteremia and/or endovascular infection.

The device and/or pocket itself can be the source of infection, usually due to contamination at the time of implantation, or can be secondary to bacteremia from a different source.

[0019] Perioperative contamination of the pacemaker pocket with skin flora appears to be the most common source of subcutaneous infection.

[0020] Cardiac device-related infective endocarditis (CDRIE) is another life-threatening condition, with increasing incidence due to growing number of implantations (81000 pacemaker implantation per year in Europe). The incidence of CDRIE reaches 0.14 percent, and is even higher after ICD implantation.

[0021] *Staphylococcus aureus* and coagulase-negative staphylococci (often *Staphylococcus epidermidis*) cause 65 to 75 percent of generator pocket infections and up to 89 percent of device-related endocarditis. Episodes arising within two weeks of implantation are more likely to be due to *S. aureus*.

[0022] Successful treatment of an infected medical device or biomaterial, regardless of the involved component, generally requires removal of the entire system and administration of antibiotics targeting the causative bacteria. Importantly, medical therapy alone is associated with high mortality and risk of recurrence.

[0023] Prosthetic valve endocarditis (PVE) is a serious infection with potentially fatal consequences.

[0024] Bacteria can reach the valve prosthesis by direct contamination intraoperatively or via hematogenous spread during the initial days and weeks after surgery. The bacteria have direct access to the prosthesis-annulus interface and to perivalvular tissue along suture pathways because the valve sewing ring, cardiac annulus, and anchoring sutures are not endothelialized early after valve implantation. These structures are coated with host proteins, such as fibronectin and fibrinogen, to which some organisms can adhere and initiate infection.

The risk of developing prosthetic valve endocarditis (PVE) is greatest during the initial three months after surgery, remains high through the sixth month, and then falls gradually with an annual rate of approximately 0.4 percent from 12 months postoperatively onward. The percentage of patients developing PVE during the initial year after valve replacement ranges from 1 to 3 percent in studies with active follow-up; by five years, the cumulative percentage ranges from 3 to 6 percent.

[0025] The most frequently encountered pathogens in early PVE (within two months of implantation) are *S. aureus* and coagulase-negative staphylococci.

[0026] The most frequently encountered pathogens in late PVE (two months after valve implantation) are streptococci and *S. aureus*, followed by coagulase-negative staphylococci and enterococci.

[0027] The coagulase-negative staphylococci causing PVE during the initial year after surgery are almost exclusively *Staphylococcus epidermidis*. Between 84 and 87 percent of these organisms are methicillin resistant and thus resistant to all of the beta-lactam antibiotics.

[0028] According to the 2008 French survey, PVE accounts for about 20 percent of all infective

endocarditis. PVE is related to health care in about 30 percent of cases. *S. aureus* is the first causative pathogen, being responsible for more than 20 percent of PVE. Importantly, when comparing data from 1999, PVE-related mortality remains high, reaching about 40 percent after surgery, and 25 percent in-hospital mortality.

[0029] Periprosthetic joint infection (PJI) occurs in 1 to 2 percent of joint replacement surgeries and is a leading cause of arthroplasty failure.

[0030] Biofilms play an important role in the pathogenesis of PJIs. Bacteria within biofilm become resistant to therapy; as a result, antibacterial therapy is often unsuccessful unless the biofilm is physically disrupted or removed by surgical debridement. Prosthetic joint infections are categorized according to the timing of symptom onset after implantation: early onset (<3 months after surgery), delayed onset (from 3 to 12 months after surgery), and late onset (>12 months after surgery). These infections have the following characteristics. Early-onset infections are usually acquired during implantation and are often due to virulent organisms, such as *Staphylococcus aureus*, or mixed infections. Delayed-onset infections are also usually acquired during implantation. Consistent with the indolent presentation, delayed infections are usually caused by less virulent bacteria, such as coagulase-negative staphylococci or enterococci. Late-onset infections resulting from hematogenous seeding are typically acute and often due to *S. aureus*, or beta hemolytic streptococci.

[0031] The management of PJIs generally consists of both surgery and antibacterial therapy.

[0032] There is therefore an urgent need in the art for a new antibacterial therapy. WO2009/034386 discloses triazolopyrimidine derivatives which are useful in the treatment of Gram-positive bacterial infections.

[0033] We have surprisingly found that certain cyclopentyl-substituted triazolo(4,5-d)pyrimidine derivatives possess antibacterial activity and can be used in the treatment or prevention of bacterial infection in a host mammal.

We have also found that such Triazolo(4,5-d)pyrimidine derivatives can also be used in a method for controlling bacterial growth in biofilm formation at early stage such as step 1 or 2 or for killing bacteria at all steps of biofilm formation including the latest step 3 wherein the biofilm has reached its maturation stage of matrix formation and start detachment from the surface with a consequent spreading of bacteria into other locations.

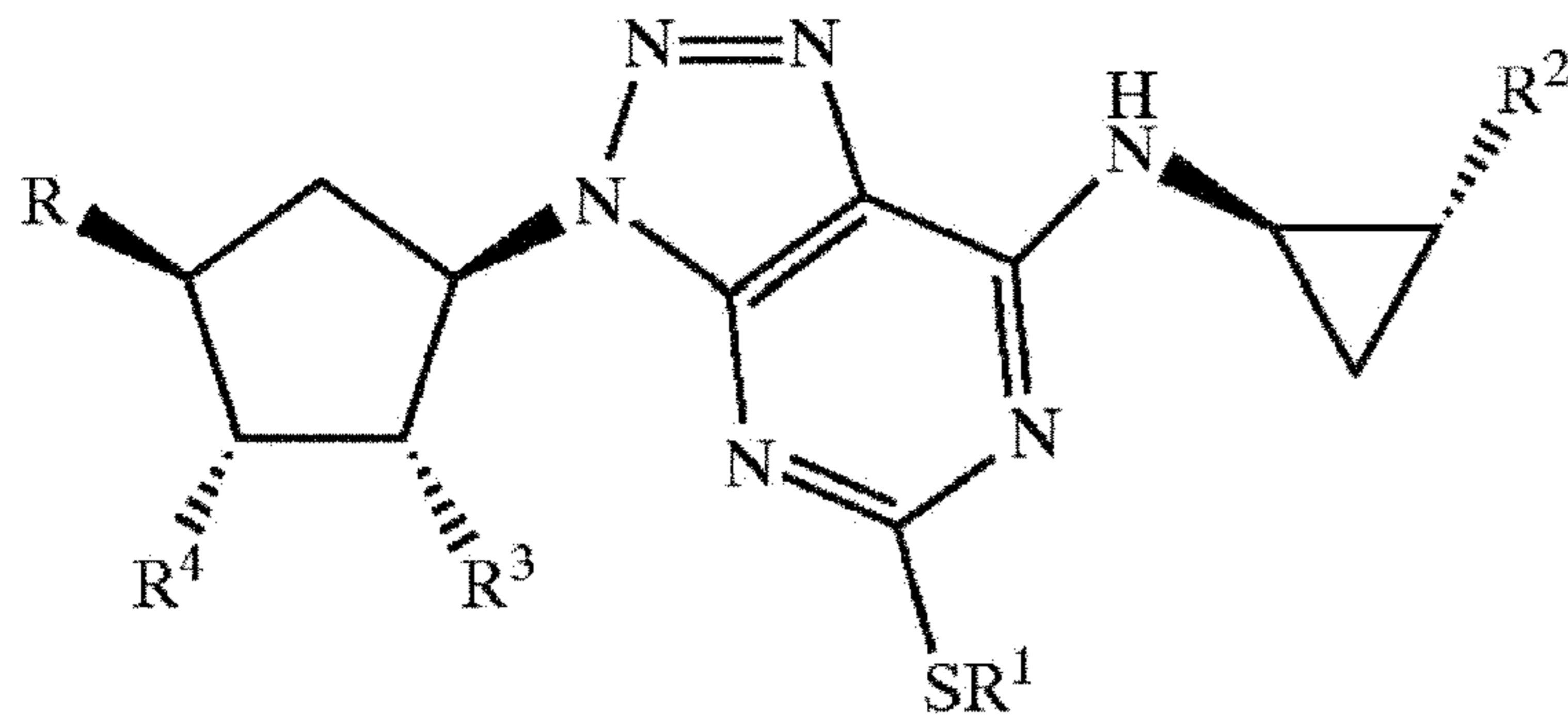
In a first aspect, the invention provides therefore Triazolo(4,5-d)pyrimidine derivatives for use in the treatment or prevention of bacterial infection in a host mammal in need of such treatment.

By bacterial infection one means particularly Gram-positive bacterial infection such as for example pneumonia, septicemia, endocarditis, osteomyelitis, meningitis, urinary tract, skin, and soft tissue infections. The source of bacterial infection is diverse, and can be caused for example by the use of implantable biomaterials.

By biomaterials, one means all implantable foreign material for clinical use in host mammals such as for prosthetic joints, pacemakers, implantable cardioverter-defibrillators, intravascular

catheters, coronary stent, prosthetic heart valves, intraocular lens, dental implants and the like.

[0034] By Triazolo(4,5-d)pyrimidine derivatives one means compounds of the following formula (I)



(I)

wherein R₁ is C₃₋₅ alkyl optionally substituted by one or more halogen atoms; R₂ is a phenyl group, optionally substituted by one or more halogen atoms; R₃ and R₄ are both hydroxyl; R is OH or XOH, wherein X is CH₂, OCH₂CH₂, or a bond;

or a pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt provided that when X is CH₂ or a bond, R₁ is not propyl; when X is CH₂ and R₁ CH₂CH₂CF₃, butyl or pentyl, the phenyl group at R₂ must be substituted by fluorine; when X is OCH₂CH₂ and R₁ is propyl, the phenyl group at R₂ must be substituted by fluorine.

[0035] Alkyl groups whether alone or as part of another group are straight chained and fully saturated.

[0036] R₁ is a C₃₋₅ alkyl optionally substituted by one or more fluorine atoms. Preferably R₁ is 3,3,3, -trifluoropropyl, butyl or propyl.

R₂ is phenyl or phenyl substituted by one or more halogen atoms. Preferably R₂ is phenyl substituted by fluorine atoms. Most preferably R₂ is 4-fluorophenyl or 3,4-difluorophenyl.

R is OH or XOH, where X is CH₂, OCH₂CH₂, or a bond ; preferably R is OH or OCH₂CH₂OH.

When X is a bond, R is OH.

Most preferred Triazolo(4,5-d)pyrimidine derivatives are the ones including R₂ as 4-fluorophenyl or 3,4-difluorophenyl and or R as OCH₂CH₂OH.

Triazolo(4,5-d)pyrimidine derivatives are well known compounds. They may be obtained according to the method described in US 6,525,060.

[0037] Triazolo(4,5-d)pyrimidine derivatives are used as medicament against platelet adhesion and aggregation that are primary steps in arterial thrombosis.

They work by antagonizing the platelet P₂Y₁₂ receptor for ADP in a reversible manner, providing antiplatelet effects after oral administration. P₂Y₁₂ is one of the two ADP receptors

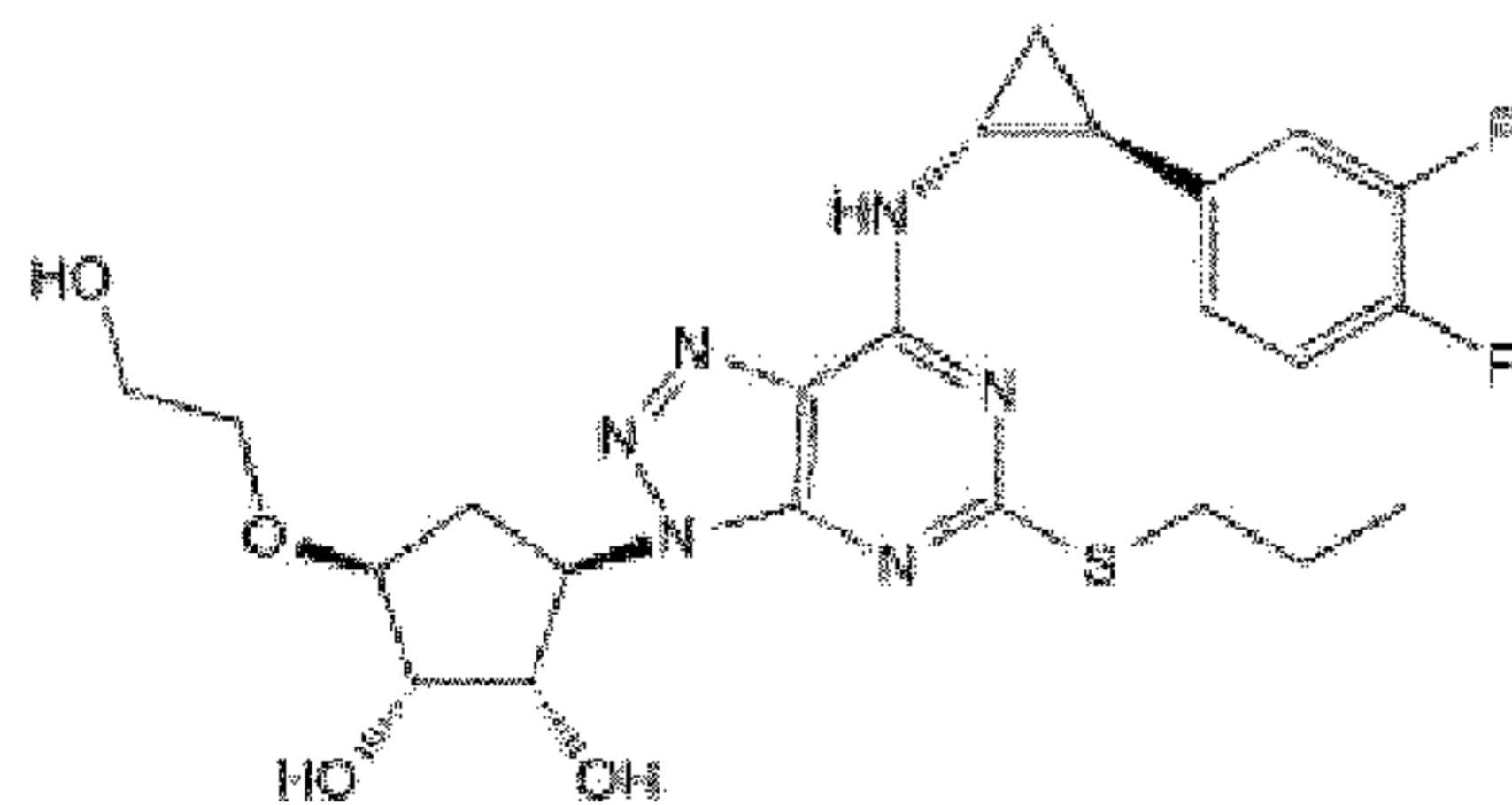
expressed by platelets, acting by amplifying platelet responses to other agonists, which stabilizes platelet aggregates and promotes thrombosis. As a consequence, P2Y12 inhibitors, alone or in combination with aspirin, significantly improve outcomes of patients with coronary artery disease and peripheral vascular disease.

We have now surprisingly found that such Triazolo(4,5-d)pyrimidine derivatives have also an antibacterial effect.

[0038] Preferred Triazolo(4,5-d)pyrimidine derivatives for use in treatment and prevention of bacterial infection are derivatives with R equals OH or OCH₂CH₂OH and /or R₂ equals 4-fluorophenyl or 3,4 difluorophenyl.

[0039] Most preferred Triazolo(4,5-d)pyrimidine derivatives for use in treatment and prevention of bacterial infection are (1R-(1 α ,2 α ,3 β (1R*,2*),5 β))-3-(7-((2-(3,4-difluorophenyl)cyclopropyl)amino)-5-((3,3,3-trifluoropropyl)thio)3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(hydroxy)cyclopentane-1,2-diol;
 (1S-(1 α ,2 α ,3 β (1R*,2*),5 β))-3-(7-((2-(3,4-difluorophenyl)cyclopropyl)amino)-5-(propylthio)(3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(2-hydroxyethoxy)cyclopentane-1,2-diol;
 (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol);
 (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(4-fluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol);
 (1S,2R,3S,4R)-4-[7-[[1R,2S)-2-(3,4-Difluorophenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentanetriol;
 and pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt.

[0040] The most preferred Triazolo(4,5-d)pyrimidine derivative for use in treatment and prevention of bacterial infection is (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol) as defined in formula (II) and also called Triafluocyl hereafter.

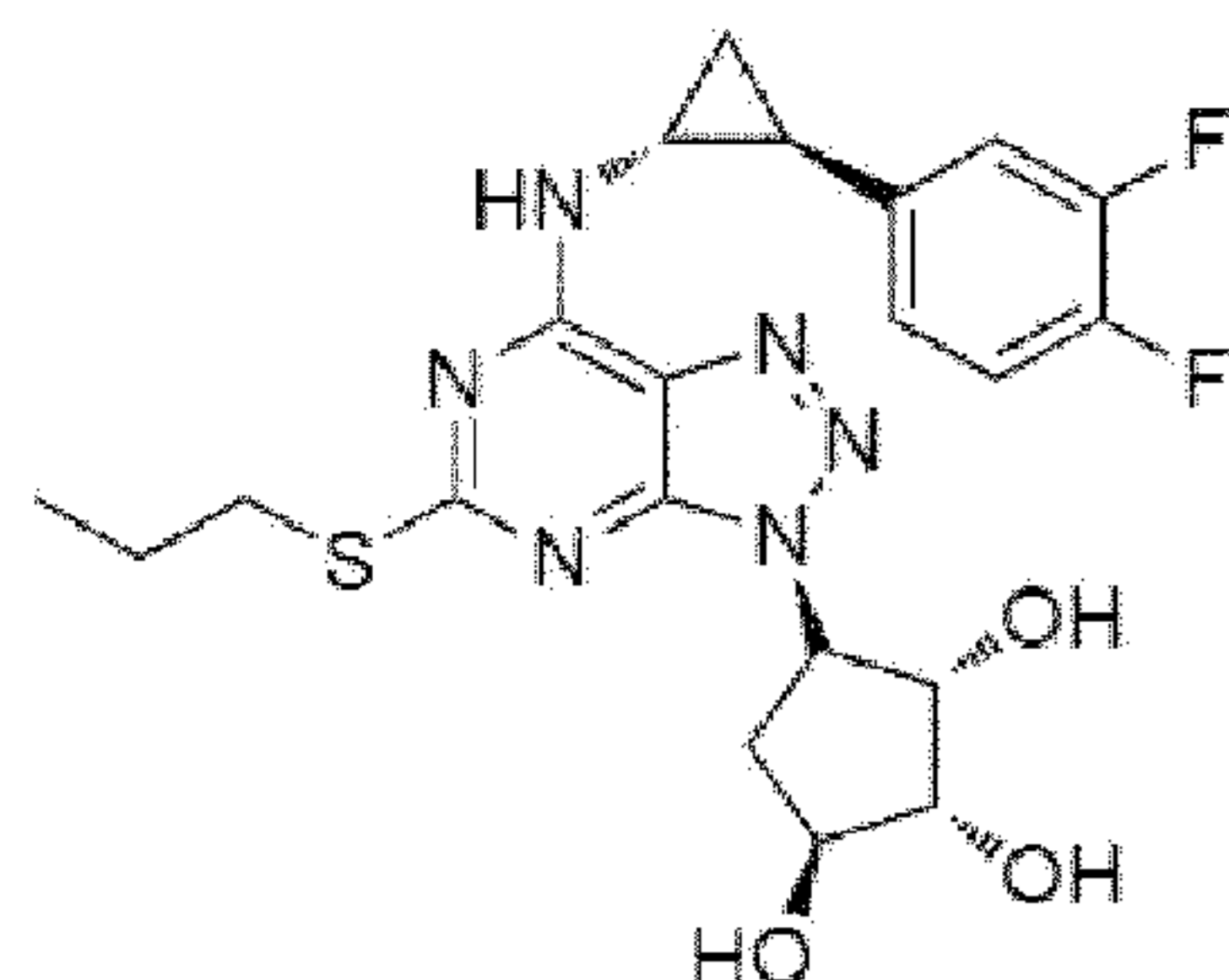


(II)

and a pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt.

[0041] Another most preferred Triazolo(4,5-d)pyrimidine derivative for use in treatment and prevention of bacterial infection is (1S,2R,3S,4R)-4-[7-[[1R,2S)-2-(3,4-

Difluorophenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentanetriol as defined in formula (III) and also called Fluometacyl hereafter



(III)

and a pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt.

[0042] According to the invention the Triazolo(4,5-d)pyrimidine derivative has to be administered to the patient over several days (especially in case of prevention). The Triazolo(4,5-d)pyrimidine derivative may be administered on their own or as a pharmaceutical composition, with non-toxic doses being inferior to 1.8 g per day.

[0043] A further preferred object of the invention is a pharmaceutical composition of Triazolo(4,5-d)pyrimidine derivative for use in the prevention or treatment of bacterial infection,

[0044] The pharmaceutical composition may be a dry powder or a liquid composition having physiological compatibility. The compositions include, in addition to triazolo(4,5-d)pyrimidine derivative, auxiliary substances, preservatives, solvents and/or viscosity modulating agents. By solvent, one means for example water, saline or any other physiological solution, ethanol, glycerol, oil such as vegetable oil or a mixture thereof. By viscosity modulating agent one means for example carboxymethylcellulose.

[0045] The Triazolo(4,5-d)pyrimidine derivative of the present invention exhibits its effects through oral, intravenous, intravascular, intramuscular, parenteral, or topical administration, and can be additionally used into a composition for parenteral administration, particularly an injection composition or in a composition for topical administration. It can also be loaded in nanoparticles for nanomedicine applications. It can be used in an aerosol composition. Such aerosol composition is for example a solution, a suspension, a micronised powder mixture and the like. The composition is administered by using a nebulizer, a metered dose inhaler or a dry powder inhaler or any device designed for such an administration.

Examples of galenic compositions include tablets, capsules, powders, pills, syrups, chewing, granules, and the like. These may be produced through well known technique and with use of typical additives such as excipients, lubricants, and binders.

Suitable auxiliary substances and pharmaceutical compositions are described in Remington's Pharmaceutical Sciences, 16th ed., 1980, Mack Publishing Co., edited by Oslo et al. Typically, an appropriate amount of a pharmaceutically-acceptable salt is used in the composition to render the composition isotonic. Examples of pharmaceutically acceptable substances include saline, Ringer's solution and dextrose solution. pH of the solution is preferably from about 5 to about 8, and more preferably from about 7 to about 7.5.

[0046] A still further preferred object of the invention is the triazolo (4,5-d)pyrimidine derivative of formula (I) for use in a method of treatment or prevention of bacterial infection in a host mammal in need of such treatment which comprises administering to the host an effective amount of triazolo(4,5-d)pyrimidine derivatives as defined in formula (I),

preferably (1R-(1 α ,2 α ,3 β (1R*,2*),5 β))-3-(7-((2-(3,4-difluorophenyl)cyclopropyl)amino)-5-((3,3,3-trifluoropropyl)thio)3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(hydroxy)cyclopentane-1,2-diol;

(1S-(1 α ,2 α ,3 β (1R*,2*),5 β))-3-(7-((2-(3,4-difluorophenyl)cyclopropyl)amino)-5-(propylthio)(3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(2-hydroxyethoxy)cyclopentane-1,2-diol;

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol);

most preferably (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(4-fluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol) as defined in formula II;

or most preferably (1S,2R,3S,4R)-4-[7-[[[(1R,2S)-2-(3,4-Difluorophenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentanetriol, as defined in formula III;

or a pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt.

[0047] In another aspect, the invention provides the use of Triazolo(4,5-d)pyrimidine derivatives, preferably (1R-(1 α ,2 α ,3 β (1R*,2*),5 β))-3-(7-((2-(3,4-difluorophenyl)cyclopropyl)amino)-5-((3,3,3-trifluoropropyl)thio)3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(hydroxy)cyclopentane-1,2-diol;

(1S-(1 α ,2 α ,3 β (1R*,2*),5 β))-3-(7-((2-(3,4-difluorophenyl)cyclopropyl)amino)-5-(propylthio)(3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(2-hydroxyethoxy)cyclopentane-1,2-diol;

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol);

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(4-fluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol);

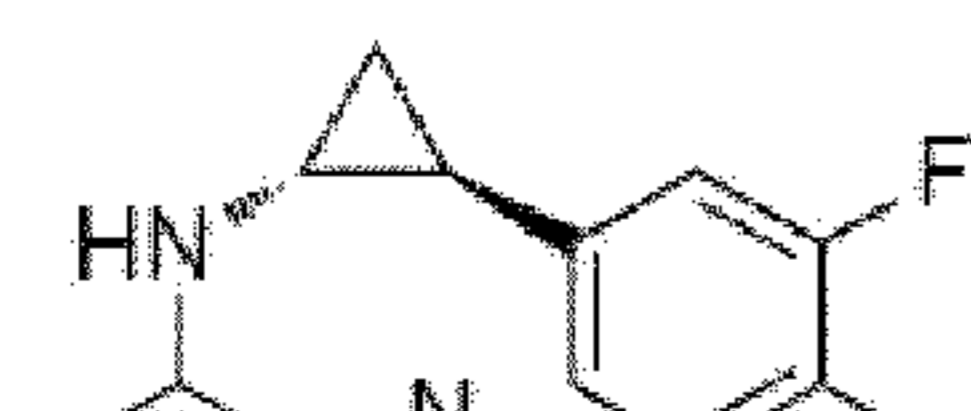
and pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt;

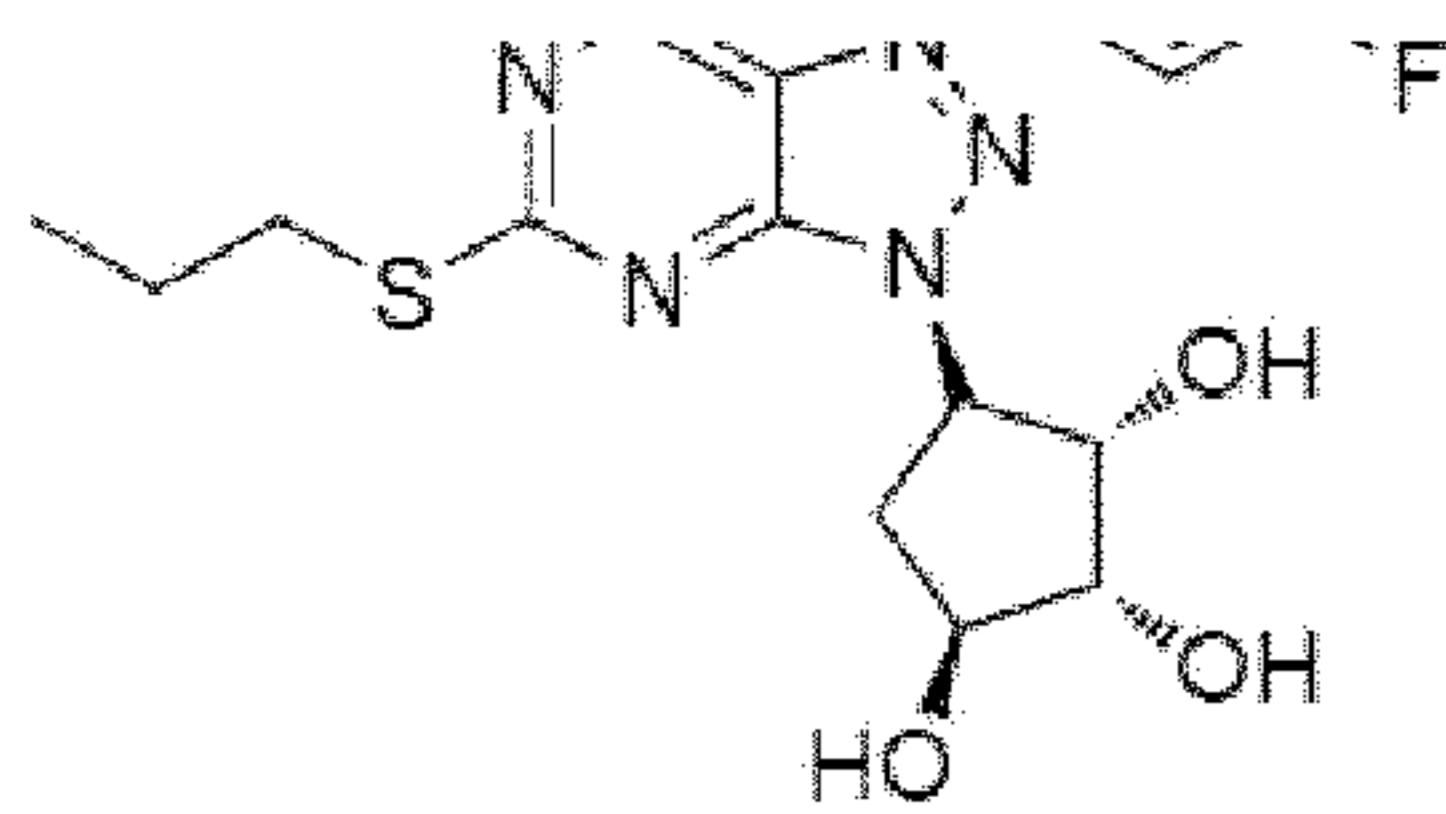
and most preferably (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol)

or a pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt;

as inhibitor of biofilm on a surface, particularly a surface of a biomaterial or of a medical device.

The most preferred inhibitor of biofilm on a surface is (1S,2R,3S,4R)-4-[7-[[[(1R,2S)-2-(3,4-Difluorophenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentanetriol, as defined in formula III





(III)

and pharmaceutical acceptable salt or solvate thereof, or a solvate thereof or a solvate of such a salt;

[0048] By surface one means any type of surface such as rubber or plastic surface as for example surface made of polyethylene, polypropylene, polyurethane, polyvinyl chloride, polyvinylpyrrolidone, polytetrafluoroethylene, silicone or the like, or copolymers but also and preferably metallic surface such as stainless steel, silver, gold, titanium, metallic alloys pyrolytic carbon, and the like. It can also be used on bioabsorbable or biomaterial surface such as biological prosthesis or devices which are made of biological material such as for example porcine or bovine pericardium

[0049] By inhibition of biofilm on a surface one means inhibition of the biofilm formation at all stages of its formation starting from a prevention or an inhibition of adherence of bacteria on the surface at step 1 but also and mainly an inhibition in bacteria grow, multiplication, and formation of microcolonies on the surface at step 2. By inhibition of biofilm one also means inhibition of the matrix at the maturation step 3 and inhibition of bacteria dispersion from the matrix in a colonisation step. By inhibition of biofilm, one also means killing bacteria at all steps of the biofilm formation.

[0050] By medical device one means biomaterial as defined above but also medical device requesting no bacterial contamination such as wound dressing, soft tissue fillers, root canal fillers, contact lens, blood bag and the like.

[0051] A last further aspect according to the invention, is a method for killing or controlling bacterial growth in biofilm formation on a surface comprising applying Triazolo(4,5-d)pyrimidine derivative on a surface either at a prevention step, reducing bacteria adherence and survival on the substrate or at a stage where the biofilm is already present, or even at a maturation step with a matrix formation wherein a more complex architecture of biofilm is established protecting bacteria as a barrier to conventional antibacterial agent.

[0052] The method of bacteria killing or prevention of bacterial growth on a surface is generally applied to biomaterials or medical devices.

[0053] The biomaterial or medical device are preferably implantable foreign material for clinical use in host mammals such as prosthetic devices, pacemakers, implantable cardioverter-defibrillators, intravascular catheters, coronary stent, heart valves, intraocular lens and the like but could be extended to other medical devices requesting no bacterial contamination such as for example wound dressings, soft tissue fillers containing local anaesthetics, root canal fillers with ancillary medicinal substances and the like.

[0054] The method of bacteria killing or prevention of bacterial growth could also be applied to surface of experimental device in need of such antibacterial treatment.

Description of the Figures

[0055]

Figure 1 illustrates a bacteriostatic and bactericidal effect of Triafluocyl on *Staphylococcus aureus*. Growth curves (A) and viable counts (B) in the presence of different concentrations of Triafluocyl or DMSO as vehicle are shown.

Figure 2 illustrates an inhibition of *Staphylococcus aureus* biofilm formation by Triafluocyl at stage 2.

Figure 3 illustrates a bacteriostatic and bactericidal effect of Triafluocyl on *Enterococcus faecalis*. Growth curves (A) and viable count (B) in the presence of different concentrations of Triafluocyl or DMSO as vehicle are shown.

Figure 4 illustrates an inhibition of *Enterococcus faecalis* biofilm formation by Triafluocyl at stage 2.

Figure 5 illustrates a bacteriostatic and bactericidal effect of Triafluocyl on *Staphylococcus epidermidis*. Growth curve (upper panel) and viable count (lower panel) in the presence of different concentrations of Triafluocyl or DMSO as vehicle.

Figure 6 illustrates an inhibition of *Staphylococcus epidermidis* biofilm formation at stage 2 by Triafluocyl.

Figure 7 illustrates a destruction of mature biofilm (stage 3: 24-hour biofilm) by Triafluocyl. Viable count of *S. epidermidis* biofilm after a 24h treatment with Triafluocyl (upper panel). Percentage of live cells in the biofilm (lower panel).

Figure 8 illustrates bactericidal activity against MRSA, GISA and VRE strains of Triafluocyl as compared to Vancomycin and Mynocycline:

Figure 8A illustrates a killing curve for methicillin-resistant *S. aureus* (MRSA).

Figure 8B illustrates a killing curve for Glycopeptide intermediate-resistant *S. aureus* (GISA).

Figure 8C illustrates a killing curve for vancomycin resistant *E. faecalis* (VRE).

Figure 9 illustrates bactericidal activity of Fluometacyl against *S. aureus* MRSA.

Figure 10A and 10B illustrate the antibacterial effect of different concentrations of Fluometacyl on *S. aureus* and *S. epidermidis* biofilm formation respectively.

Examples:

[0056] The invention is illustrated hereafter by the following non limiting examples.

[0057] We have conducted in vitro experiments, using *S. aureus*, *S. epidermidis*, and *E. faecalis* as clinically relevant Gram-positive bacterial strains.

[0058] The tests were performed in accordance with the recommendations of the European Committee on Antimicrobial Susceptibility Testing (EUCAST).

Example 1: use of (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol) or Triafluocyl (Cayman, item No15425).

[0059] *S. aureus* (American Type Culture Collection, ATCC 25904) was grown overnight in Tryptic Soy Broth (TSB) medium, diluted 1:100 in fresh TSB, and incubated aerobically at 37°C until bacteria growth reached a logarithmic phase ($OD_{600} = 0.25-0.3$).

[0060] Increasing concentrations of Triafluocyl (Cayman Chemical, Item No. 15425) or vehicle (DMSO) was then added in 5 ml of bacteria suspensions. Bacterial growth was measured after different time intervals (20-100 min) by spectrophotometry (OD_{600}) and by counting the colony-forming units after plating appropriate culture dilutions on TS agar plates.

[0061] Bacteriostatic and bactericidal effects were measured with Triafluocyl. In Figure 1 kinetics of *S. aureus* growth in the presence of an increasing concentrations (1µg/ml to 20 µg/ml) of Triafluocyl were measured by turbidity measurement (upper graph), and viable count (lower graph). Data represent medians ± range (n = 3). * p<0.05; ** p<0.01, *** p<0,001, Triafluocyl vs vehicle.

[0062] As shown in Figure 1, while a concentration of 10 µg/ml Triafluocyl was able to inhibit bacterial growth, 20 µg/ml Triafluocyl displayed potent bactericidal effect.

Example 2: use of (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol) or Triafluocyl as inhibitor of biofilm formation.

[0063] *S. aureus* (ATCC 25904) was grown overnight in TSB medium, before being diluted 100 fold in fresh TSB, and incubated aerobically at 37°C until bacteria culture reached an OD_{600} of

0.6 (corresponding to approximately $1-3 \times 10^8$ CFU/ml). Bacteria cultures were then diluted to 1×10^4 CFU/ml in fresh TSB. 800 μ l aliquots of diluted bacteria suspensions were distributed in each well of a 24-well plate. Bacteria were allowed to adhere for 4 hours under static conditions at 37°C. After removing media, wells were rinsed 2 times with PBS to eliminate planktonic bacteria and re-filled with TSB supplemented with 0.5 % glucose

[0064] Triafluocyl or DMSO as vehicle was then added at desired concentration and plates were incubated at 37°C for 20 hours. After incubation, wells were washed and stained with 0.5 % (w/v) crystal violet for 30 minutes, washed again and the dye was solubilized by adding 20 % acetic acid (v/v in water) before reading absorbance at 595 nm.

[0065] *S. aureus* biofilms were formed on polystyrene surface in the presence of increasing concentrations of Triafluocyl or DMSO as vehicle. In figure 2, Biofilm mass is presented as percentage of values obtained in the presence of DMSO (* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$, Triafluocyl versus DMSO, n= 4).

[0066] Triafluocyl significantly reduces *S. aureus* biofilm formation at all concentrations tested. In the presence of 10 μ g/ml Triafluocyl, no biofilm could form on polystyrene surface.

Example 3: use of (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorophenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentanediol) or Triafluocyl (Cayman Chemical, Item No. 15425) .

[0067] *E. faecalis* (ATCC 29212) was grown overnight in Brain heart infusion (BHI) medium, diluted 1:100 in fresh BHI, and incubated aerobically at 37°C until bacteria growth reached a logarithmic phase ($OD_{600} = 0.25-0.3$).

[0068] Increasing concentrations of Triafluocyl (Cayman Chemical, Item No. 15425) or DMSO as vehicle was then added in 5 ml of bacteria suspensions. Bacterial growth was measured after different time intervals (30-120 min) by spectrophotometry (OD_{600}) and by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates.

[0069] Bacteriostatic and bactericidal effects were measured with Triafluocyl. In Figure 3 kinetics of *E. faecalis* growth in the presence of an increasing concentrations (5 μ g/ml to 40 μ g/ml) of Triafluocyl were measured by turbidity measurement (upper graph), and viable count (lower graph). Data represent medians \pm range (n = 3).

[0070] As shown in Figure 3, while a concentration of 10 μ g/ml Triafluocyl was able to inhibit bacterial growth, 20 μ g/ml Triafluocyl and more importantly 40 μ g /ml displayed potent bactericidal effects.

Example 4: use of Triafluocyl as inhibitor of biofilm formation.

[0071] *E. faecalis* (ATCC 29212) was grown overnight in BHI medium, before being diluted 100 fold in fresh TSB, and incubated aerobically at 37°C until bacteria culture reached an OD₆₀₀ of 0.6 (corresponding to approximately 2-5x10⁸ CFU/ml). Bacteria cultures were then diluted to 1x10⁴ CFU/ml in fresh TSB. 800 µl aliquots of diluted bacteria suspensions were distributed in each well of a 24-well plate. Bacteria were allowed to adhere for 4 hours under static conditions at 37°C. After removing media, wells were rinsed 2 times with PBS to eliminate planktonic bacteria and re-filled with TSB supplemented with 0.5 % glucose

[0072] Triafluocyl or DMSO as vehicle was then added at desired concentration and plates were incubated at 37°C for 20 hours. After incubation, wells were washed and stained with 0.5 % (w/v) crystal violet for 30 minutes, washed again and the dye was solubilized by adding 20 % acetic acid (v/v in water) before reading absorbance at 595 nm.

[0073] *E. faecalis* biofilms were formed on polystyrene surface in the presence of increasing concentrations of Triafluocyl or DMSO as vehicle. In figure 2, Biofilm mass is presented as percentage of values obtained in the presence of DMSO (**P* < 0.05; ** *P* < 0.01; *** *P* < 0.001, Triafluocyl versus DMSO, n= 4).

[0074] Triafluocyl significantly reduces *E. faecalis* biofilm formation at a starting concentration of 10 µg/ml. In the presence of 40 µg/ml Triafluocyl, no biofilm could form on polystyrene surface.

Example 5: Time-kill study of Triafluocyl against *S. epidermidis*

[0075] To evaluate Triafluocyl antibacterial effect we have tested *S. epidermidis* liquid growth in the presence of different Triafluocyl concentrations in logarithmic phase. In this phase usually bacteria are highly susceptible to agents with bactericidal activity because they are rapidly dividing.

[0076] A 1:100 inoculum in 50ml TSB of an O/N culture of *S. epidermidis* was cultured for 3hr up to its logarithmic phase (OD₆₀₀ = 0,26 and ≈ 3x10⁸ CFU/ml).

[0077] Bacteria were split in several tubes containing different concentrations of DMSO as vehicle alone or in combination with Triafluocyl in TSB and grown for 100min at 37°C with 220rpm shaking, the OD₆₀₀ was measured every 20min.

[0078] Compared to the growth with DMSO (0,25%) we observed a dose-dependent inhibition of *S. epidermidis* growth between 10µg/ml and 20µg/ml Triafluocyl (Figure 5). At 50µg/ml we

observed a slight bacteriostatic activity, confirmed by the number of viable cells at 80min, 3×10^8 CFU/ml, equal to the number of bacteria in the untreated control at the beginning of the assay (Figure 5).

[0079] Moreover, we have tested the effect of Triafluocyl on a low-density inoculum, 0.08×10^6 CFU/ml, from a culture of *S. epidermidis* in logarithmic phase. We have followed the growth for 4hr with or without Triafluocyl and measured the OD₆₀₀: already 5µg/ml of Triafluocyl decreased the OD by 50% compared to the growth in absence of Triafluocyl at the same time point; 10µg/ml and 20µg/ml inhibited growth (OD value equal to OD at the beginning of the growth) (data not shown).

[0080] This means that the lower the inoculum density the lower the concentration of Triafluocyl to slow down growth or kill bacteria.

Example 6: Triafluocyl prevents *S. epidermidis* biofilm formation

[0081] To study the effect of Triafluocyl on biofilm formation, *S. epidermidis* in early logarithmic phase (5×10^8 CFU/ml) was plated in a 24-well plate and let to adhere at the bottom of the well for 4hr at 37°C in static conditions. After 4hr incubation, planktonic bacteria were removed and adherent bacteria were washed twice in TSB. Fresh TSB medium supplemented or not with 0.25% glucose was added to the well with 5 different concentrations of Triafluocyl and incubated for 24 hours. Wells were washed 3 times with NaCl 0.9% and incubated for 1hr at RT with Crystal Violet 1% solution in dH₂O to stain the biofilm.

[0082] Wells were washed 3 times with dH₂O to eliminate unbound crystal violet, then 400µl Acetic Acid 10% was added and incubated at RT for 10min. Absorbance was measured in triplicate at 570nm, reflecting total biomass of the biofilm (live and dead bacteria).

[0083] Triafluocyl affected biofilm formation (Figure 6): already at 5µg/ml, in the absence of glucose, it inhibited biofilm formation by 50%, while in presence of glucose we reach 50% biofilm reduction only at 20µg/ml Triafluocyl.

[0084] The concentration of Triafluocyl that inhibits at least 90% biofilm formation is called minimum biofilm inhibitory concentration (MBIC). Triafluocyl MBIC for *S. epidermidis* is 50µg/ml both in the presence and in the absence of glucose.

Example 7: Triafluocyl destroys *S. epidermidis* mature biofilm

[0085] In another experiment we let adhere 0.5×10^8 CFU/ml *S. epidermidis* cells for 4hr and let the biofilm form for additional 24hr in presence of 0.25% glucose, at this point we treated the

biofilm with several concentrations of Triafluocyl for 24hr in TSB with 0.25% glucose and determined the viable count (Figure 7) as well as the percentage of live cells using the BacLight bacterial viability kit (Molecular Probes).

[0086] For biofilm analysis, we first washed the biofilm to eliminate all planktonic bacteria and then the biofilm was detached mechanically using a scraper. To assure that the aggregates from the biofilm were completely dissociated, the suspension of cells was passed through a needle (0.5x16mm) and a dilution was plated on TSA plates.

[0087] Only the highest concentration of Triafluocyl, 50µg/ml, was effective in reducing the number of viable cells in the biofilm with a reduction of almost 3 log (from 1.1×10^8 CFU/ml in the control to 1.5×10^5 CFU/ml).

[0088] In the same experiment we also determined the percentage of live and dead bacteria. To do so we followed the procedure of the kit LIVE/DEAD from Molecular Probes. Briefly, the biofilm was resuspended in a solution of 0.9% NaCl and cells were stained with a mixture of SYTO9 (green fluorescence) and propidium iodide (PI) (red fluorescence) for 15 min in the dark. Stained cells were transferred in a 96-well plate and fluorescence was measured using the Enspire Spectrophotometer with excitation wavelength of 470nm and emission spectra in the range of 490 - 700nm. SYTO9 dye (green fluorescence 500-520nm) penetrates all the cells (dead and live) and binds to DNA, while PI (red fluorescence in the range 610-630nm) enters only in dead cells with a damaged cell membrane. When PI and SYTO9 are in the same cell the green fluorescence intensity decreases. Therefore, in a population of cells with high percentage of dead cells there is a reduction in the emission spectra of the green fluorescence, because there is more PI staining. The ratio of fluorescence intensity (green/live) is plotted against a known percentage of live cells to obtain a standard curve and the percentage of live cells in our samples is obtained by extrapolation (Figure 7). Triafluocyl, at concentrations of 20µg/ml and 50µg/ml reduced the percentage of live bacteria to 80% and 30%, respectively.

Example 8: Triafluocyl antibacterial effects on *S. epidermidis*: determination of Minimal Inhibitory Concentration (MIC) and Minimal Bactericidal Concentration (MBC)

[0089] The Minimal Inhibitory Concentration (MIC) and the Minimal Bactericidal Concentration (MBC) of Triafluocyl were determined in *Staphylococcus epidermidis* (ATCC 35984, also known as RP62A) according to EUCAST (European Committee on Antimicrobial Susceptibility Testing) recommendations.

[0090] Briefly, a single colony grown on a Tryptic Soy Agar (TSA) plate was resuspended and cultured in Tryptic Soy Broth (TSB) overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:50 inoculum in Mueller-Hinton broth (MHB) was incubated in aerobic conditions for 3hr and an inoculum of 1:100 dilution, corresponding to 3×10^5 CFU/ml, was

incubated in presence or absence of different concentrations of Triafluocyl in 1% DMSO (vehicle). After O/N growth the OD of each culture was measured at 600nm in a spectrophotometer (OD₆₀₀). The MIC represents the concentration at which there is no visible growth of bacteria, *i.e.* ΔOD at 600nm equal to zero (blank is the medium alone).

[0091] We have also determined the MBC, *i.e.* the concentration at which the liquid culture, when spread on TSA plates, will not produce any colony.

[0092] The MIC for Triafluocyl against *S.epidermidis* is equal to 12 ± 3 µg/ml and the MBC is 17 ± 3 µg/ml (two biological replicates, detection limit 10⁻³).

[0093] The Minimum Duration for killing 99,9% *S.epidermidis* (MDK99,9) by Triafluocyl, a tolerance metric according to the EUCAST, was 2 hours.

Example 9: Triafluocyl antibacterial effects on *S. aureus*: determination of Minimal Inhibitory Concentration (MIC) and Minimal Bactericidal Concentration (MBC)

[0094] Further experiments were conducted using different strains of *S. aureus*, as clinically relevant Gram-positive bacterial strains: ATCC 25904, ATCC 6538, methicillin-resistant *S. aureus* (MRSA) ATCC BAA-1556, Glycopeptide intermediate-resistant (GISA) *S. aureus* Mu-50 (ATCC 700695) in order to determine the Minimal Inhibitory Concentration (MIC) which is the minimal concentration required to prevent bacterial growth; the Minimal Bactericidal Concentration (MBC) which determines the lowest concentration at which an antimicrobial agent kill a particular microorganism and a Minimum Duration for killing 99,9% bacteria (MDK99,9) which is a tolerance metric according to the EUCAST.

[0095] MIC determination: A single colony selected from the different strains of *S. aureus* is resuspended and cultured in the appropriate medium overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum in Mueller-Hinton broth (MHB) was incubated in aerobic conditions for 3hr (OD=0,08-0,1) and an inoculum of 1:300 dilution, corresponding to 3x10⁵ CFU/ml, was incubated in presence or absence of different concentrations of Triafluocyl in 1% DMSO. After O/N growth the OD of each culture was measured at 600nm in a spectrophotometer (OD₆₀₀). The MIC represents the concentration at which there is no visible growth of bacteria, *i.e.* ΔOD at 600nm equal to zero (blank is the medium alone). MIC for Triafluocyl against *S. aureus* ATCC 25904, ATCC 6538, methicillin-resistant *S. aureus* (MRSA) ATCC BAA-1556, Glycopeptide intermediate-resistant (GISA), and *S. aureus* Mu-50 (ATCC 700695) were 20, 20, 15, and 20 µg/ml, respectively.

[0096] MBC and MDK99,9 determination: A single colony selected from the different strains of *S. aureus* is resuspended and cultured in the appropriate medium (TSB, or BHI) overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum in the appropriate medium was incubated in aerobic conditions for 2h. The culture is then challenged

with triafluocyl at MIC concentration or higher concentrations. Bacterial growth was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates. The concentration that kill at least 99,9% of the started inoculum in 24h is defined as the MBC. And the real time needed is defined as the MDK_{99,9}. MBC for Triafluocyl against *S. aureus* ATCC 25904, ATCC 6538, methicillin-resistant *S. aureus* (MRSA) ATCC BAA-1556, Glycopeptide intermediate-resistant (GISA), and *S. aureus* Mu-50 (ATCC 700695) were 20 µg/ml for each of them. MDK_{99,9} for Triafluocyl against *S. aureus* ATCC 25904, ATCC 6538, methicillin-resistant *S. aureus* (MRSA) ATCC BAA-1556, Glycopeptide intermediate-resistant (GISA), and *S. aureus* Mu-50 (ATCC 700695) were 10, 6, 2, and 14 hours, respectively.

Example 10: Triafluocyl antibacterial effects on *E. faecalis*: determination of Minimal Inhibitory Concentration (MIC) and Minimal Bactericidal Concentration (MBC)

[0097] Further experiments were conducted using different strains of *E. faecalis*, as clinically relevant Gram-positive bacterial strains: *E. faecalis* vancomycin-resistant (VRE) ATCC BAA-2365, and *E. faecalis* ATCC 29212 in order to determine the Minimal Inhibitory Concentration (MIC) which is the minimal concentration required to prevent bacterial growth; the Minimal Bactericidal Concentration (MBC) which determines the lowest concentration at which an antimicrobial agent kill a particular microorganism and a Minimum Duration for killing 99,9% bacteria (MDK_{99,9}) which is a tolerance metric according to the EUCAST.

[0098] MIC determination: A single colony selected from the different strains of *E. faecalis* is resuspended and cultured in the appropriate medium overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum in Mueller-Hinton broth (MHB) was incubated in aerobic conditions for 3hr (OD=0,08-0,1) and an inoculum of 1:300 dilution, corresponding to 3×10^5 CFU/ml, was incubated in presence or absence of different concentrations of Triafluocyl in 1% DMSO. After O/N growth the OD of each culture was measured at 600nm in a spectrophotometer (OD₆₀₀). The MIC represents the concentration at which there is no visible growth of bacteria, *i.e.* ΔOD at 600nm equal to zero (blank is the medium alone). MIC for Triafluocyl against *E. faecalis* vancomycin-resistant (VRE) ATCC BAA-2365, and *E. faecalis* ATCC 29212 were 20 and 40 µg/ml, respectively.

[0099] MBC and MDK_{99,9} determination: A single colony selected from the different strains of *E. faecalis* is resuspended and cultured in the appropriate medium (TSB, or BHI) overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum in the appropriate medium was incubated in aerobic conditions for 2h. The culture is then challenged with triafluocyl at MIC concentration or higher concentrations. Bacterial growth was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates. The concentration that kill at least 99,9% of the started inoculum in 24h is defined as the MBC. And the real time needed is defined as the MDK_{99,9}. MBC for Triafluocyl against *E. faecalis* vancomycin-resistant (VRE) ATCC BAA-2365 was 20

µg/ml. MDK_{99,9} for Triafluocyl against *E. faecalis* vancomycin-resistant (VRE) ATCC BAA-2365 was 24 hours.

Example 11: Triafluocyl antibacterial effects on *Streptococcus agalactiae*: determination of Minimal Inhibitory Concentration (MIC) and Minimal Bactericidal Concentration (MBC)

[0100] Further experiments were conducted using *S. agalactiae* (ATCC 12386), as clinically relevant Gram-positive bacterial strains in order to determine the Minimal Inhibitory Concentration (MIC) which is the minimal concentration required to prevent bacterial growth; the Minimal Bactericidal Concentration (MBC) which determines the lowest concentration at which an antimicrobial agent kill a particular microorganism and a Minimum Duration for killing 99,9% bacteria (MDK_{99,9}) which is a tolerance metric according to the EUCAST.

[0101] MIC determination: A single colony selected from the different strains of *S. agalactiae* (ATCC 12386) is resuspended and cultured in the appropriate medium overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum in Mueller-Hinton broth (MHB) was incubated in aerobic conditions for 3hr (OD=0,08-0,1) and an inoculum of 1:300 dilution, corresponding to 3×10^5 CFU/ml, was incubated in presence or absence of different concentrations of Triafluocyl in 1% DMSO. After O/N growth the OD of each culture was measured at 600nm in a spectrophotometer (OD₆₀₀). The MIC represents the concentration at which there is no visible growth of bacteria, *i.e.* ΔOD at 600nm equal to zero (blank is the medium alone). MIC for Triafluocyl against *S. agalactiae* (ATCC 12386) was 40 µg/ml.

[0102] MBC and MDK_{99,9} determination: A single colony selected from *S. agalactiae* (ATCC 12386) is resuspended and cultured in the appropriate medium (TSB, or BHI) overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum in the appropriate medium was incubated in aerobic conditions for 2h. The culture is then challenged with triafluocyl at MIC concentration or higher concentrations. Bacterial growth was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates. The concentration that kill at least 99,9% of the started inoculum in 24h is defined as the MBC. And the real time needed is defined as the MDK_{99,9}. MBC for Triafluocyl against *S. agalactiae* (ATCC 12386) was 40 µg/ml. MDK_{99,9} for Triafluocyl against *S. agalactiae* (ATCC 12386) was 1 hour.

[0103] The results of all experiments are illustrated in Table 1 and in figures 8 A,B,C, wherein the effect of Triafluocyl on resistant strains such as **MRSA**: methicillin-resistant *S. aureus*; **GISA**: Glycopeptideintermediate-resistant *S. aureus*; **VRE**: vancomycin-resistant *E. faecalis* is shown.

Table 1 **MIC**: minimal inhibitory concentration; **MBC**: minimal bactericidal concentration (cut-off = 99,9% reduction in CFU); **MDK_{99,9}**: time(h) needed to kill 99,9% of the started inoculum;

nd: not determined.

Strains	Resistance	MIC µg/ml	MBC µg/ml	MDK 99,9 Time (h)
<i>S. aureus</i> (ATCC25904)		20	20	10
<i>S. aureus</i> (ATCC6538)		20	20	6
<i>S. aureus</i>	MRSA	15	20	2
<i>S. aureus</i> -Mu50	GISA	20	20	14
<i>S. epidermidis</i>		15	20	2
<i>E. faecalis</i>		40	nd	nd
<i>E. faecalis</i>	VRE	20	20	24
<i>S. agalactiae</i>		40	40	1

[0104] Figure 8A also illustrates a comparison between the antibacterial effects of Triafluocyl, Vancomycin and Minocycline on MRSA.

[0105] *S. aureus* MRSA (ATCC BAA-1556) was grown overnight in brain heart infusion (BHI) medium, diluted 1:100 in fresh BHI, and incubated aerobically at 37°C until bacteria growth reached a logarithmic phase ($OD_{600} = 0.25-0.3$).

[0106] Triafluocyl (Cayman Chemical, Item No. 15425) (20µg/ml), Vancomycin (Sigma, 4µg/ml or 10µg/ml), Minocycline (Sigma, 8µg/ml) or a solvent (DMSO) were added to 5 ml of *S. aureus* MRSA suspensions.

[0107] Bacterial growth for *S. aureus* MRSA was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates.

[0108] One clearly observes that Triafluocyl causes a decrease of *S. aureus* MRSA viable count as early as after the first two hours, at which time doses of Vancomycin and Minocycline equal to 10- and 8-fold MIC, respectively, were ineffective. Over the 24h-experiment, the bactericidal effect of Vancomycin and Minocyclin remained less efficient than the one of Triafluocyl.

[0109] Figure 8B) illustrates a comparison between the antibacterial effect of Triafluocyl and Minocycline on *S. aureus* GISA.

[0110] *S. aureus* Mu50 GISA was grown overnight in brain heart infusion (BHI) medium, diluted 1:100 in fresh BHI, and incubated aerobically at 37°C until bacteria growth reached a logarithmic phase ($OD_{600} = 0.25-0.3$).

[0111] Triafluocyl (Cayman Chemical, Item No. 15425) (20µg/ml), Minocycline (Sigma, 8µg/ml) or vehicle (DMSO) were then added in 5 ml of bacteria suspensions. Bacterial growth was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates.

[0112] Here again Triafluocyl (20µg/ml) had a quicker and more efficient antibacterial effect than a high dose of Minocycline (10µg/ml).

[0113] Figure 8C illustrates a comparison between Triafluocyl and Minocycline on *E. faecalis* VRE.

[0114] *E. faecalis* VRE (ATCC BAA-2365) was grown overnight in brain heart infusion (BHI) medium, diluted 1:100 in fresh BHI, and incubated aerobically at 37°C until bacteria growth reached a logarithmic phase ($OD_{600} = 0.2-0.25$).

[0115] Triafluocyl (Cayman Chemical, Item No. 15425) (20µg/ml), Minocycline (Sigma, 10µg/ml) or vehicle (DMSO) was then added in 5 ml of bacteria suspensions. Bacterial growth was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates.

[0116] Here Triafluocyl (20µg/ml) showed bactericidal effect while a high dose of Minocycline (10µg/ml) was only bacteriostatic.

Example 9: Fluometacyl antibacterial effects on gram-positive bacteria strains: *S. aureus*, *S. epidermidis*, *E. faecalis*.

[0117] Susceptibility testing: MIC and MBC determination:

The Minimal Inhibitory Concentration (MIC) and the Minimal Bactericidal Concentration (MBC) of Fluometacyl were determined on several gram-positive strains (**Table 2**) following EUCAST (European Committee on Antimicrobial susceptibility Testing) recommendations.

[0118] For MIC determination a single colony was resuspended and cultured in the appropriate bacteria-specific medium (TSB: Tryptic Soy Broth for *S. aureus* atcc 25904 and *S. epidermidis* and BHI: brain-heart infusion medium for all the other strains) overnight (O/N) in aerobic conditions (37°C with 220rpm shaking), next day a 1:100 inoculum was incubated in Mueller-Hinton broth (MHB) in aerobic conditions for 3hr ($OD_{600}=0,08-0,1$). A further inoculum, 1:300 dilution of the MHB culture, corresponding to 3×10^5 CFU/ml, was grown in presence or absence of different concentrations of Fluometacyl, 1% DMSO in MHB for 20hr.

[0119] For MBC determination a 1:100 inoculum of an O/N culture (prepared like before) was incubated in aerobic conditions for 2h in bacteria-specific medium. The culture was then challenged with Fluometacyl at the MIC concentration or higher. Bacterial growth was

measured after different time intervals by counting the colony-forming units (CFU) after plating appropriate culture dilutions on bacteria-specific medium agar plates. The concentration that kills at least 99,9% of the started inoculum in 24h is defined as the MBC.

Table 2: MIC and MBC determination for different strains. **MRSA:** methicillin-resistant *S. aureus*; **GISA:** Glycopeptide intermediate-resistant *S. aureus*; **VRE:** vancomycin-resistant Enterococcus. **MIC:** minimal inhibitory concentration; **MBC:** minimal bactericidal concentration (cut-off = 99,9% reduction in CFU).

Strains	Resistance	MIC μM	MBC μM
<i>S. aureus</i> (ATCC25904)		30-38	38
<i>S. aureus</i>	MRSA	20-30	38
<i>S. aureus</i> -MU50	GISA	30-38	38
<i>S. epidermidis</i>		30	38
<i>E. faecalis</i>	VRE	38	38

Time-kill study of Fluometacyl against methicillin-resistant *S. aureus*

[0120] *S. aureus* MRSA (ATCC BAA-1556) was grown overnight in BHI medium, then a 1:100 inoculum was diluted in fresh BHI and incubated aerobically at 37°C until bacteria growth reached a logarithmic phase ($\text{OD}_{600} = 0.25-0.3$). The culture was split into two and challenged with 38 μM Fluometacyl (= 18.2 $\mu\text{g}/\text{ml}$) or DMSO (Ctrl). Bacterial growth was measured after different time intervals by counting the colony-forming units after plating appropriate culture dilutions on BHI agar plates. (N=2)

Example 10: Fluometacyl antibacterial effects on biofilm formation

[0121] *Staphylococcus aureus* (ATCC 25904) or *Staphylococcus epidermidis* (ATCC 35984) were grown overnight in TSB medium, before being diluted 100 fold in fresh TSB, and incubated aerobically at 37°C until bacteria culture reached an OD_{600} of 0.6 (corresponding to approximately $1-3 \times 10^8$ CFU/ml). Bacteria cultures were then diluted to 1×10^4 CFU/ml in fresh TSB. Aliquots of 800 μl diluted bacteria suspensions were distributed in each well of a 24-well plate. Bacteria were allowed to adhere for 4 hours under static conditions at 37°C. After removing the media, wells were rinsed 2 times with PBS to eliminate planktonic bacteria and re-filled with TSB supplemented with 0.5 % glucose containing Fluometacyl at desired concentration or DMSO alone (Ctrl). The 24-well plates were incubated at 37°C for 20 hours. Wells were then washed and stained with 0.5 % (w/v) crystal violet for 30 minutes and rinsed with PBS 4 times. The dye was solubilized by adding 20 % acetic acid (v/v in water) before reading absorbance at 595 nm. Figure 10A and Figure 10B show Fluometacyl effect on *S. aureus* and *S. epidermidis* biofilm formation respectively at all concentrations tested. In

presence of 38 μ M Fluometacyl, both *S. aureus* and *S. epidermidis* could not form any biofilm.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- [WO2009034386A](#) [0032]
- [US6525060B](#) [0036]

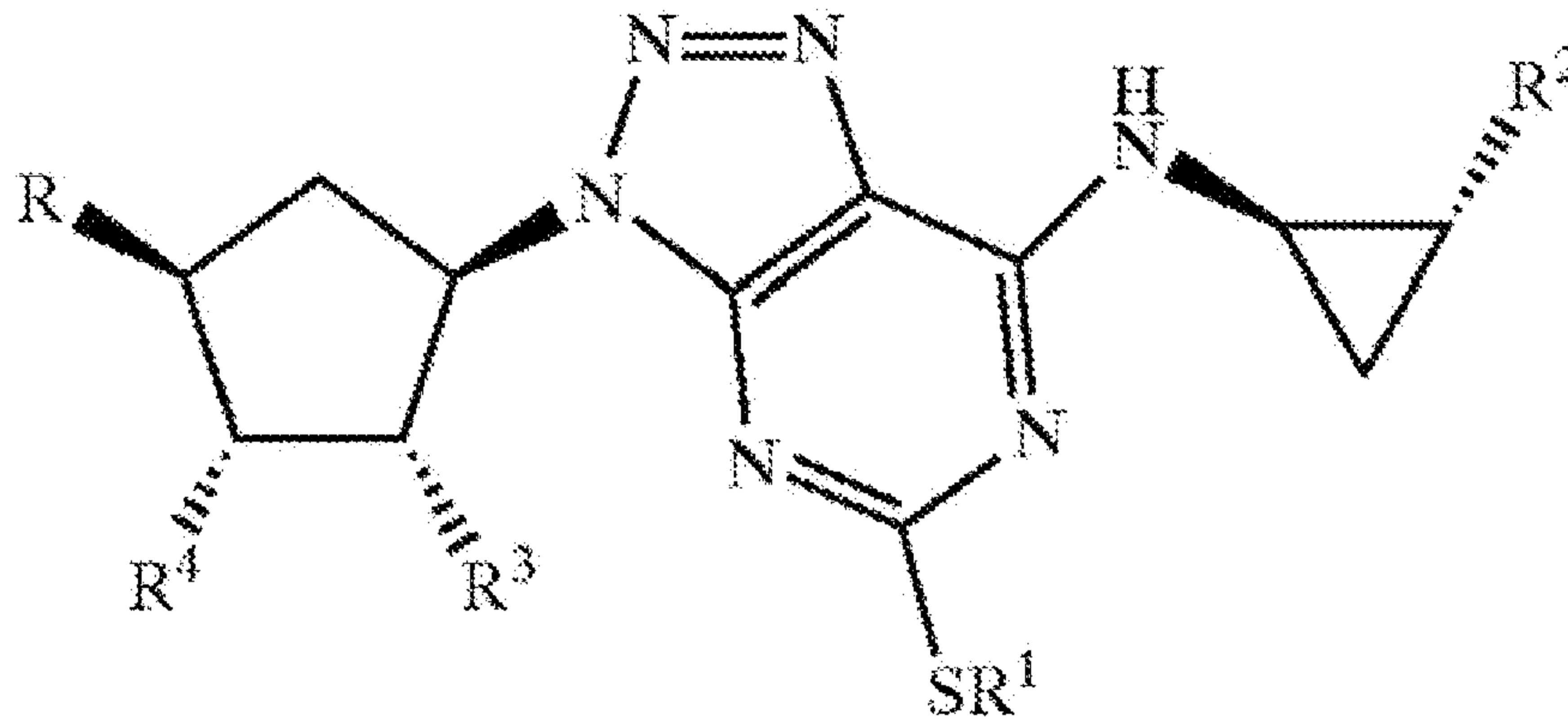
Non-patent literature cited in the description

- According to Eggiman American Society for Microbiology Press 20000000247- [\[0017\]](#)
- Remington's Pharmaceutical Sciences Mack Publishing Co. 19800000 [\[0045\]](#)

NY ANVENDELSE AF TRIAZOLO(4,5-D)PYRIMIDINDERIVATER TIL
FOREBYGGELSE OG BEHANDLING AF BAKTERIEL INFEKTION

PATENTKRAV

1. Triazolo(4,5-d)pyrimidinderivat med formlen (I)



hvor R₁ er C₃₋₅-alkyl, eventuelt substitueret med et eller flere halogenatomer, R₂ er en phenylgruppe, eventuelt substitueret med et eller flere halogenatomer, R₃ og R₄ begge er hydroxyl, R er XO₂H, hvor X er CH₂, OCH₂CH₂ eller en binding, eller et farmaceutisk acceptabelt salt eller solvat deraf, eller et solvat af et sådant salt under forudsætning af, når X er CH₂ eller en binding, at R₁ ikke er propyl, når X er CH₂, og R₁ er CH₂CH₂CF₃, butyl eller pentyl, skal phenylgruppen ved R₂ være substitueret med fluor, når X er OCH₂CH₂, og R₁ er propyl, skal phenylgruppen ved R₂ være substitueret med fluor, til anvendelse til behandling eller forebyggelse af bakteriel infektion hos et værtspattedyr, der har behov for en sådan behandling.

2. Triazolo(4,5-d) pyrimidinderivat til anvendelse ifølge krav 1, hvor R₂ er phenyl substitueret med fluoratomer.
3. Triazolo(4,5-d) pyrimidinderivat til anvendelse ifølge et hvilket som helst af kravene 1 til 2, hvor R er OH eller OCH₂CH₂OH.
4. Triazolo(4,5-d) pyrimidinderivat til anvendelse ifølge et hvilket som helst af kravene 1 til 3, hvor R er OH.
5. Triazolo(4,5-d) pyrimidinderivat til anvendelse ifølge et hvilket som helst af kravene

1 til 4, der er valgt blandt:

(1R-(1 α , 2 α , 3 β (1R*, 2*),5 β))-3-(7-((2-(3,4-difluorphenyl)cyclopropyl)amino)-5-((3,3,3-trifluorpropyl)thio)3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(hydroxy)cyclopentan-1,2-diol;

(1S-(1 α , 2 α , 3 β (1R*, 2*),5 β))-3-(7-((2-(3,4-difluorphenyl)cyclopropyl)amino)-5-(propylthio)(3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(2-hydroxyethoxy)cyclopentan-1,2-diol;

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorphenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentandiol);

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(4-fluorphenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentandiol);

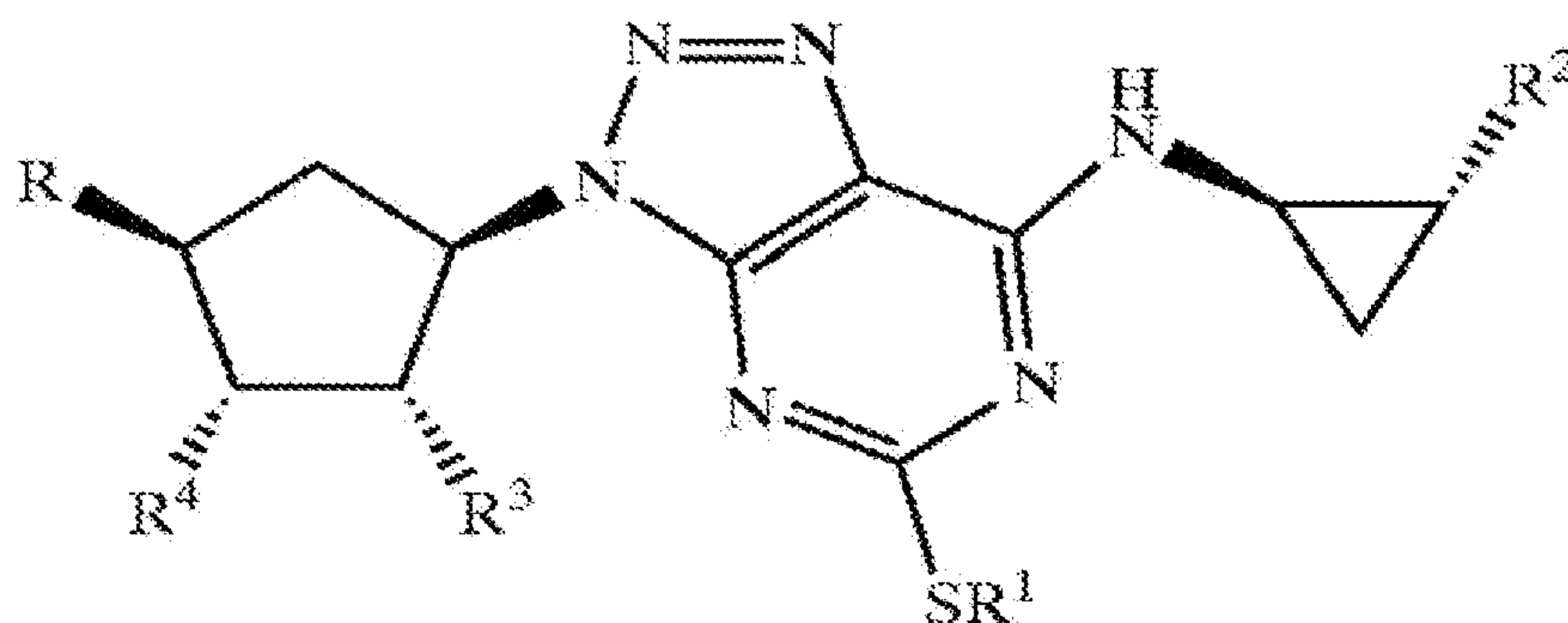
1S,2R,3S,4R)-4-[7-[[1R,2S)-2-(3,4-difluorphenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentantriol;

og et farmaceutisk acceptabelt salt eller solvat deraf eller et solvat deraf eller et solvat af et sådant salt.

6. Triazolo(4,5-d)pyrimidinderivat til anvendelse ifølge et hvilket som helst af kravene 1 til 3 og 5, der er (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorphenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentandiol), også kaldet triafluocyl.

7. Triazolo(4,5-d)pyrimidinderivat til anvendelse ifølge et hvilket som helst af kravene 1 til 5, der er 1S,2R,3S,4R)-4-[7-[[1R,2S)-2-(3,4-difluorphenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentantriol, også kaldet fluometacyl.

8. Ex vivo-anvendelse af et triazolo(4,5-d)pyrimidinderivat med formlen (I)



hvor R_1 er C_{3-5} -alkyl, eventuelt substitueret med et eller flere halogenatomer, R_2 er en phenylgruppe, eventuelt substitueret med et eller flere halogenatomer, R_3 og R_4 begge er hydroxyl, R er XOH , X er CH_2 , OCH_2CH_2 eller en binding, eller et farmaceutisk acceptabelt salt eller solvat deraf, eller et solvat af et sådant salt under forudsætning af, når X er CH_2 eller en binding, at R_1 ikke er propyl, når X er CH_2 , og R_1 er $CH_2CH_2CF_3$, butyl eller pentyl, skal phenylgruppen ved R_2 være substitueret med fluor, når X er OCH_2CH_2 , og R_1 er propyl, skal phenylgruppen ved R_2 være substitueret med fluor, som hæmmer af biofilmdannelse på en overflade.

9. Ex vivo-anvendelse af triazolo(4,5-d) pyrimidinderivatet ifølge krav 8, hvor R_2 er phenyl substitueret med fluoratomer.

10. Ex vivo-anvendelse af triazolo(4,5-d) pyrimidinderivatet ifølge et hvilket som helst af krav 8 eller 9, hvor R er OH eller OCH_2CH_2OH .

11. Ex vivo-anvendelse af triazolo(4,5-d) pyrimidinderivatet ifølge et hvilket som helst af kravene 8 til 10, hvor R er OH .

12. Ex vivo-anvendelse af triazolo(4,5-d) pyrimidinderivatet ifølge et hvilket som helst af kravene 8 til 11, der er valgt blandt:

(1R-(1 α , 2 α , 3 β (1R*, 2*),5 β))-3-(7-((2-(3,4-difluorphenyl)cyclopropyl)amino)-5-((3,3,3-trifluorpropyl)thio)3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(hydroxy)cyclopentan-1,2-diol;

(1S-(1 α , 2 α , 3 β (1R*, 2*),5 β))-3-(7-((2-(3,4-difluorphenyl)cyclopropyl)amino)-5-(propylthio)(3H-1,2,3-triazolo(4,5d)pyrimidin-3-yl)5(2-hydroxyethoxy)cyclopentan-1,2-diol;

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorphenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentandiol);

(1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(4-fluorphenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentandiol);

1S,2R,3S,4R)-4-[7-[[1R,2S)-2-(3,4-difluorphenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentantriol;

og et farmaceutisk acceptabelt salt eller solvat deraf eller et solvat deraf eller et solvat af et sådant salt.

13. Ex vivo-anvendelse af triazolo(4,5-d)pyrimidinderivatet ifølge et hvilket som helst af kravene 8 til 10 og 12, der er (1S,2S,3R,5S)-3-[7-[(1R,2S)-2-(3,4-difluorphenyl)cyclopropylamino]-5-(propylthio)-3H-[1,2,3]-triazolo[4,5-d]pyrimidin-3-yl]-5-(2-hydroxyethoxy)-1,2-cyclopentandiol), også kaldet triafluocyl.

14. Ex vivo-anvendelse af triazolo(4,5-d)pyrimidinderivatet ifølge et hvilket som helst af kravene 8 til 12, der er

1S,2R,3S,4R)-4-[7-[[[(1R,2S)-2-(3,4-difluorphenyl)cyclopropyl]amino]-5-(propylthio)-3H-1,2,3-triazolo[4,5-d]pyrimidin-3-yl]-1,2,3-cyclopentantriol, også kaldet fluometacyl.

15. Farmaceutisk sammensætning, der omfatter triazolo(4,5-d)pyrimidinderivatet med formlen (I) ifølge et hvilket som helst af kravene 1 til 7,

til anvendelse til behandling eller forebyggelse af bakteriel infektion hos et værtspattedyr, der har behov for en sådan behandling.

16. Triazolo(4,5-d) pyrimidinderivat til anvendelse ifølge et hvilket som helst af kravene 1 til 7 eller farmaceutisk sammensætning til anvendelse ifølge krav 15, hvor anvendelsen omfatter topisk indgivelse af triazolo(4,5-d)pyrimidinderivatet til værtspattedyret.

17. Ex vivo-fremgangsmåde til at dræbe bakterier eller forhindre bakterievækst ved dannelse af biofilm, hvilken fremgangsmåde omfatter anvendelse af en effektiv mængde triazolo(4,5-d)pyrimidinderivat med formlen (I) ifølge et hvilket som helst af kravene 8 til 14 ved påføring på en overflade.

18. Fremgangsmåde ifølge krav 17, hvor den effektive mængde er mellem 20 og 100 µg/ml.

19. Fremgangsmåde ifølge krav 17 eller 18, hvor overfladen tilhører et biomateriale, fortrinsvis en kardiovaskulær anordning, mere fortrinsvis en hjerteklap eller en pacemaker.

DRAWINGS

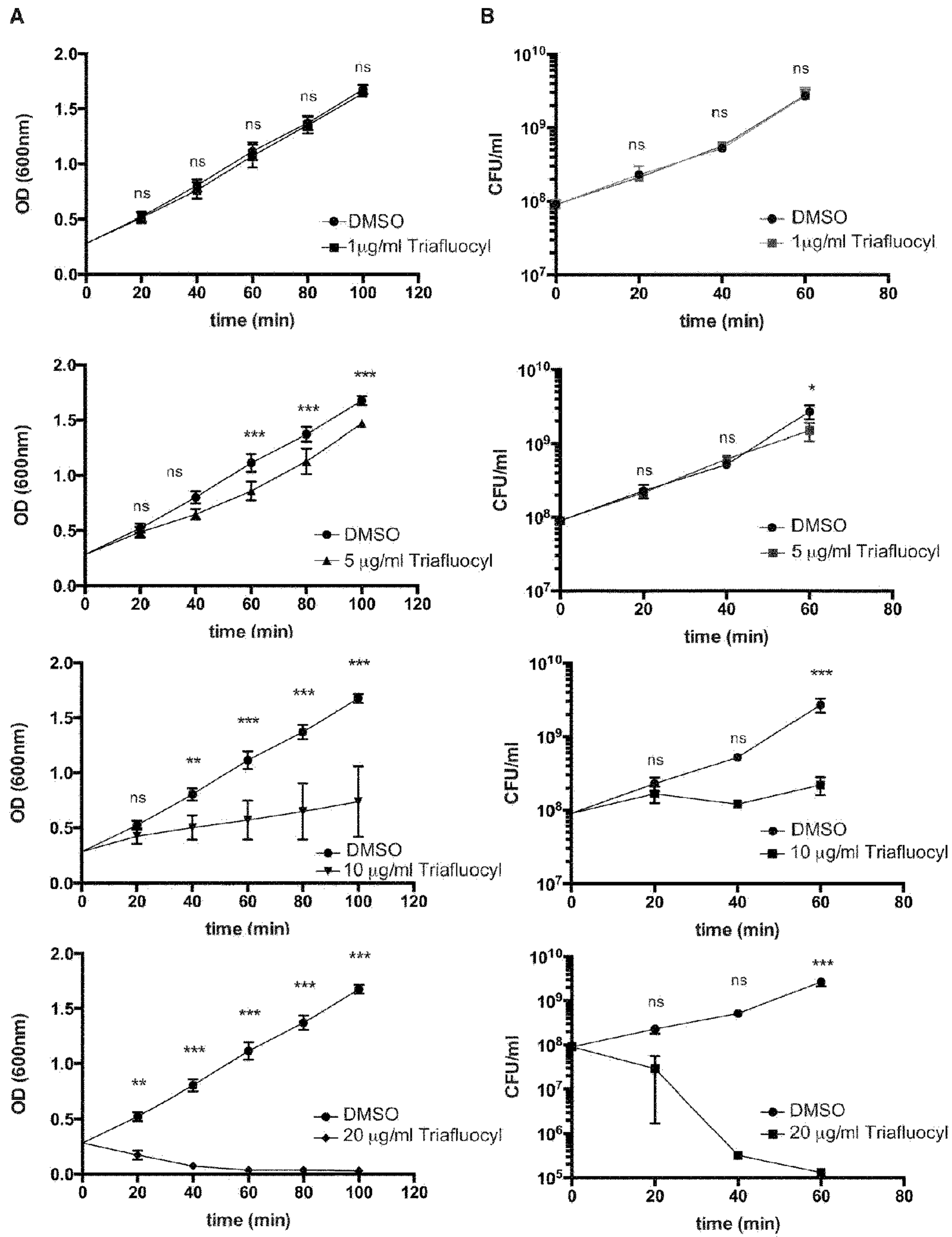


Figure 1

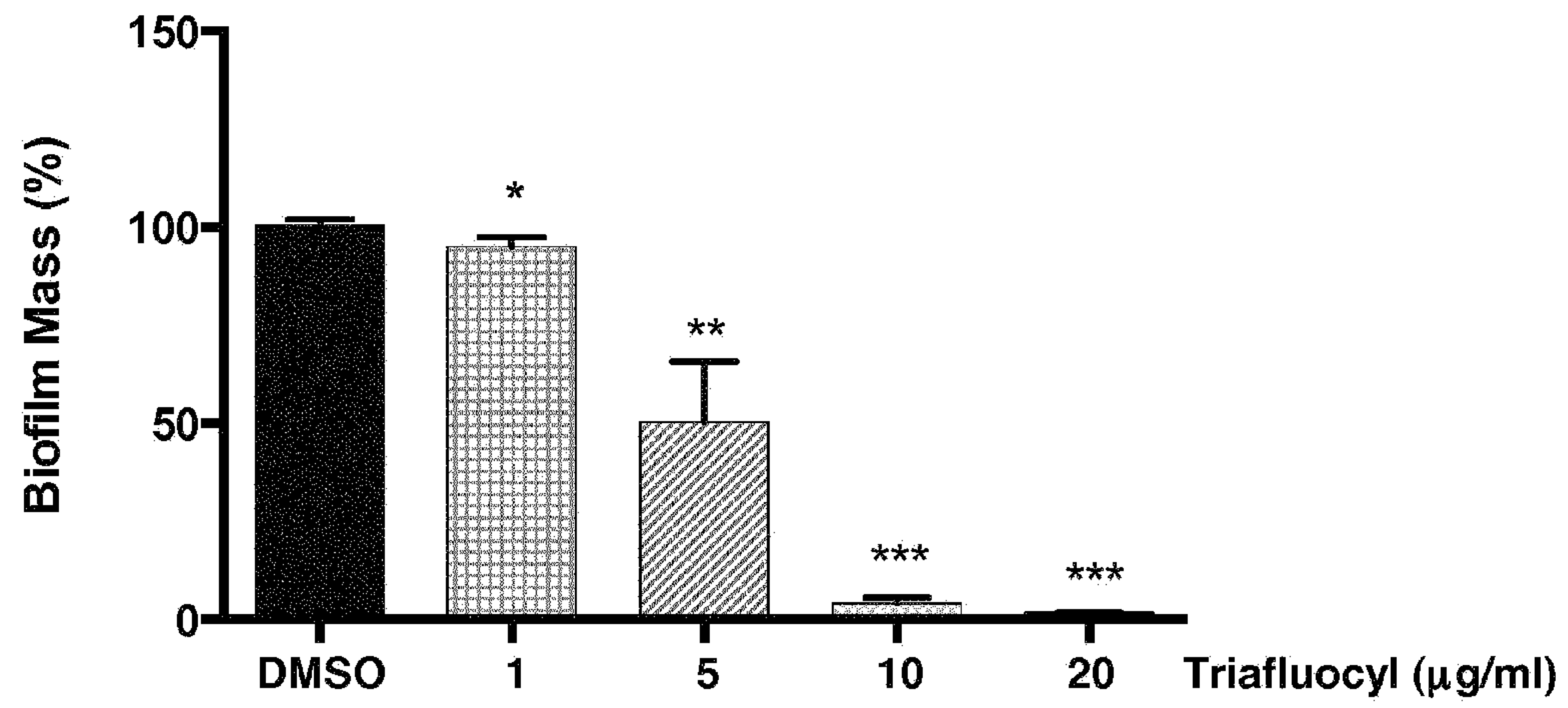


Figure 2

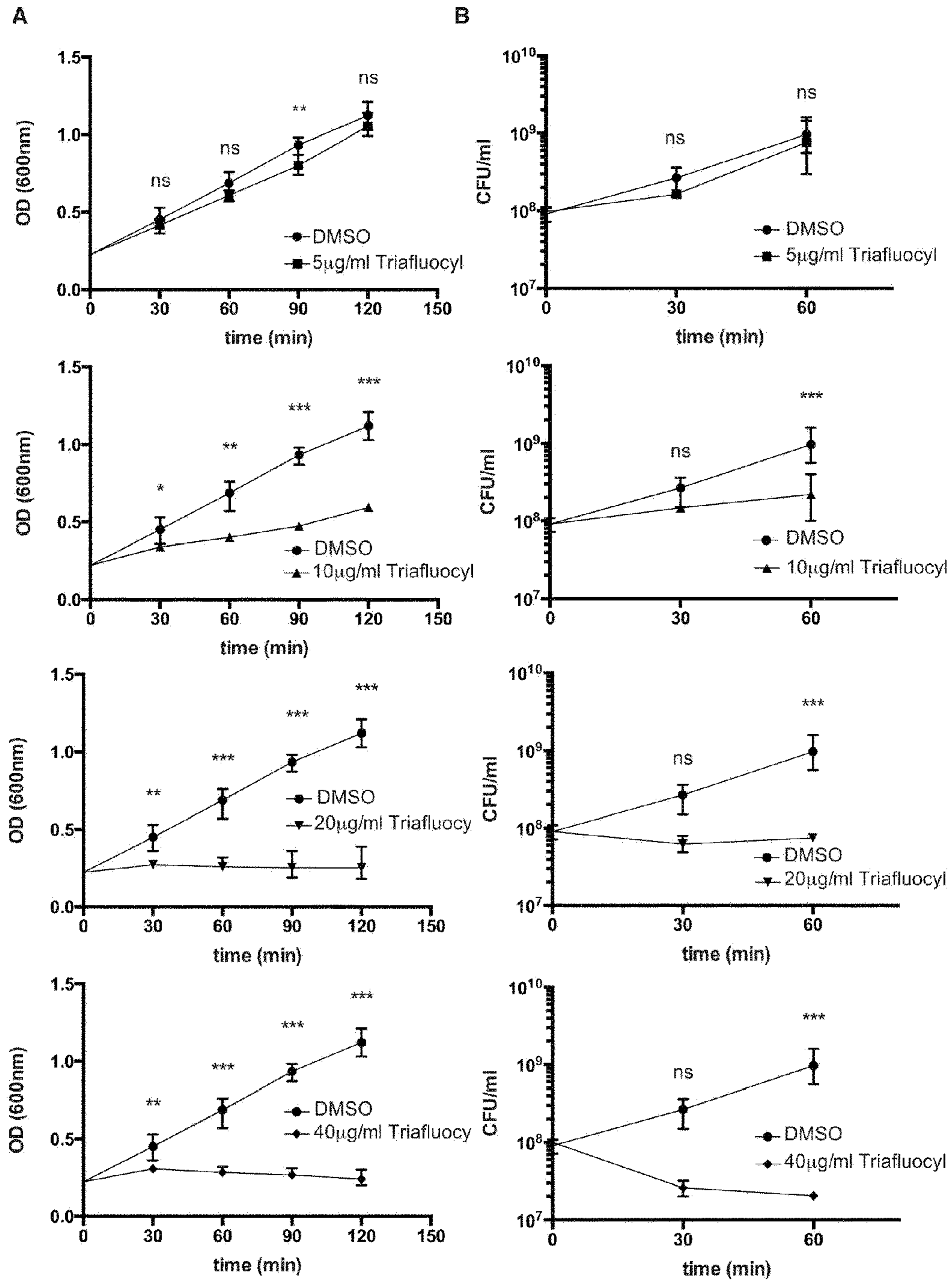


Figure 3

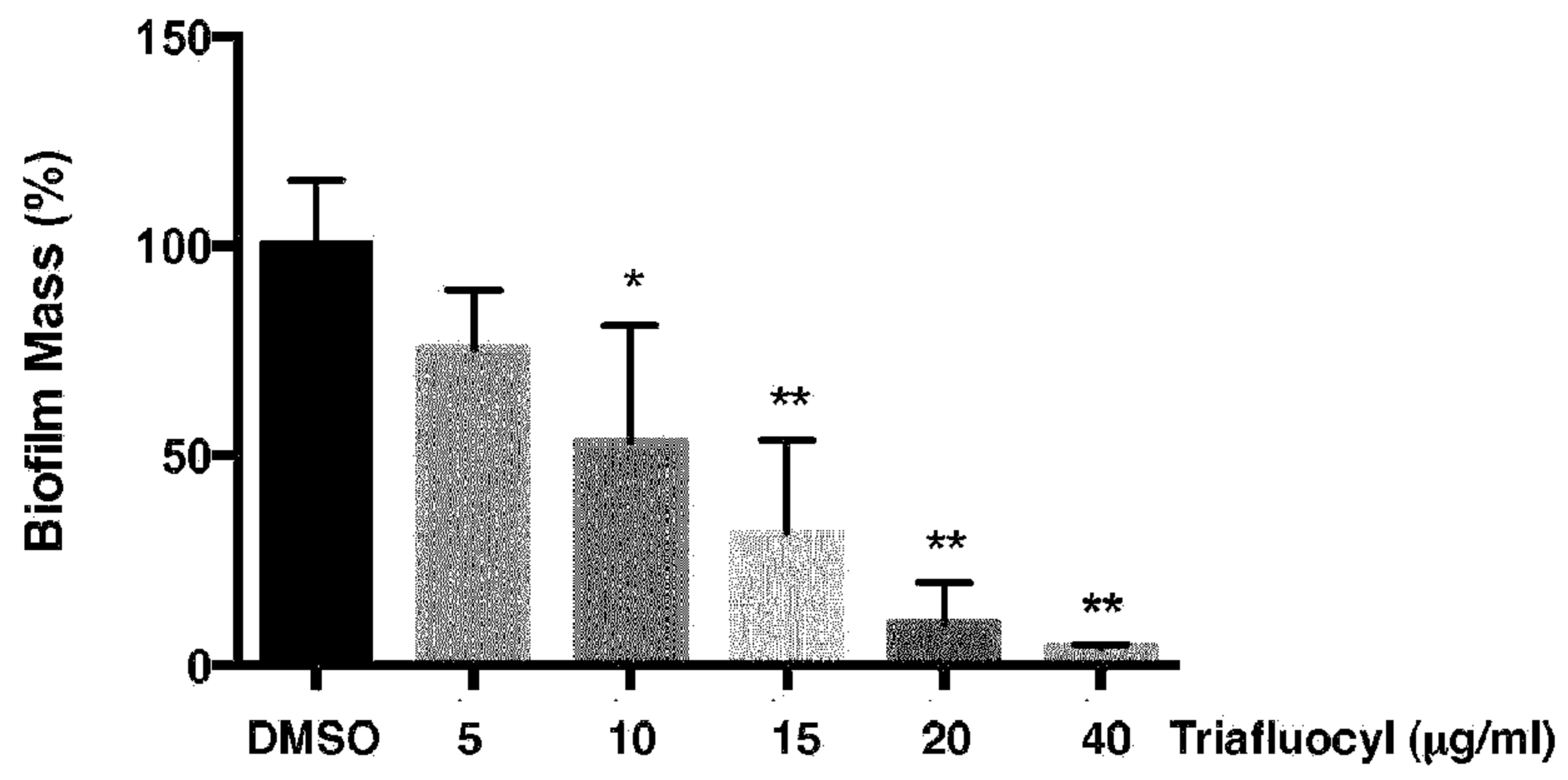


Figure 4

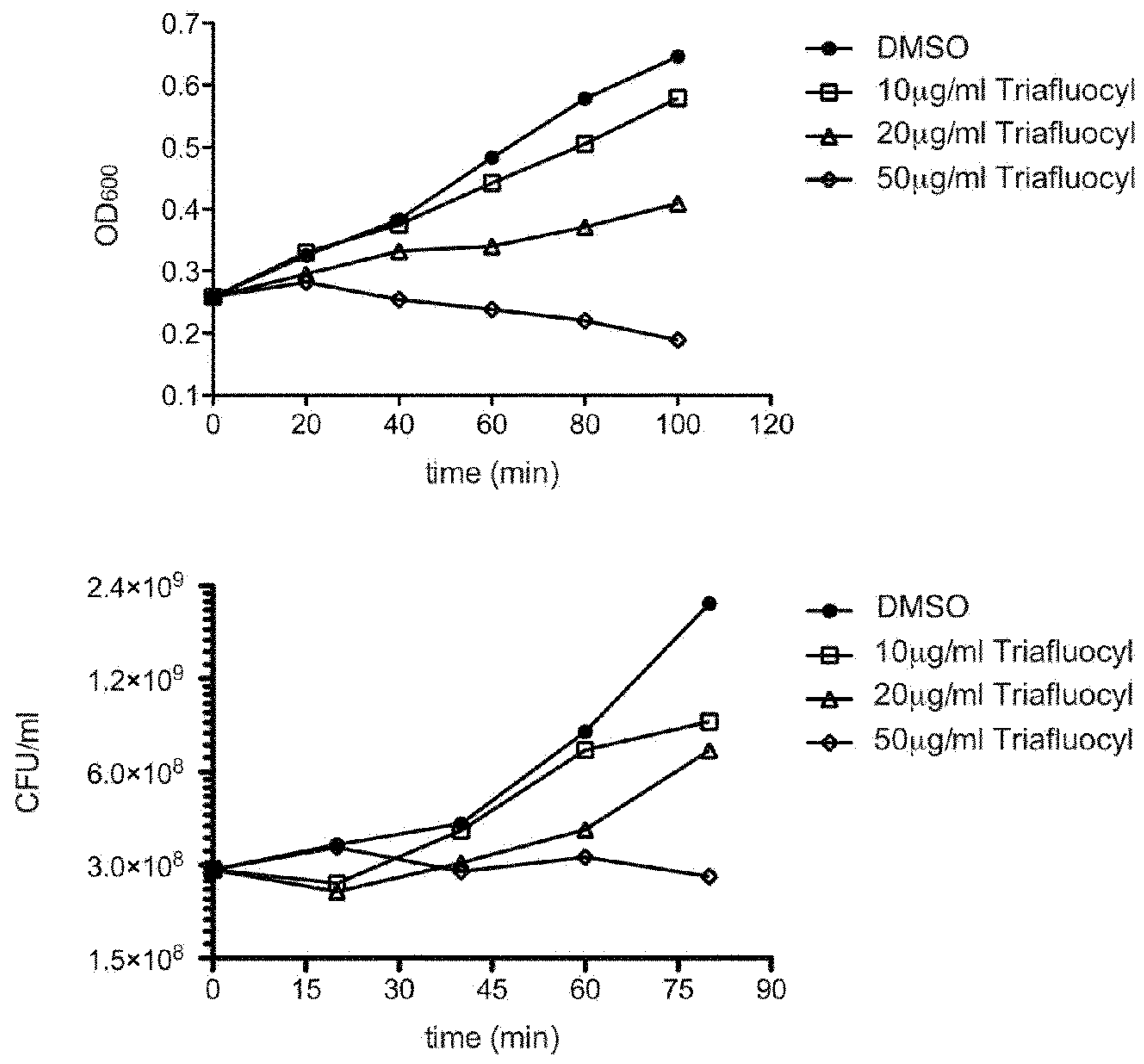


Figure 5



Figure 6

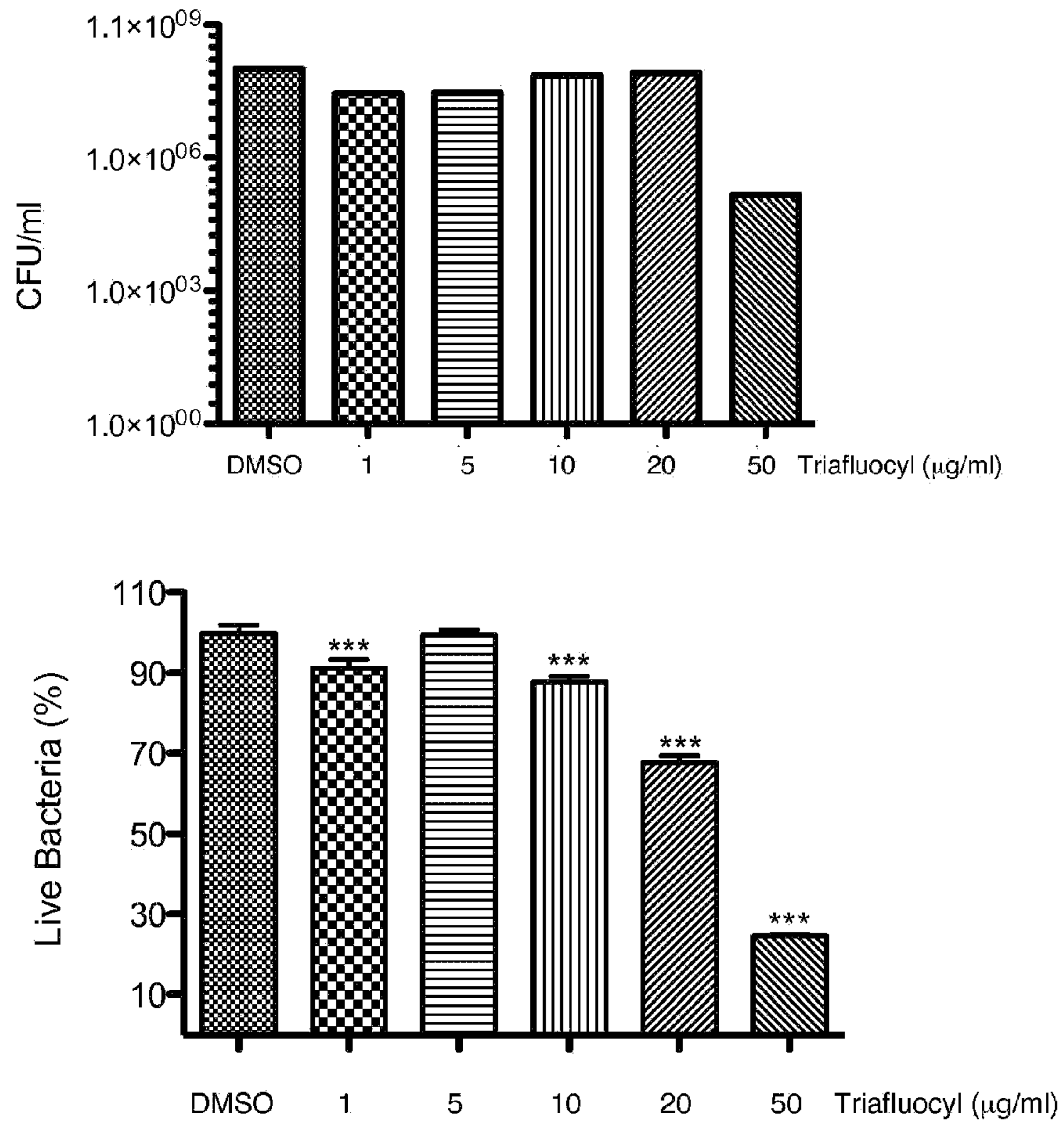


Figure 7

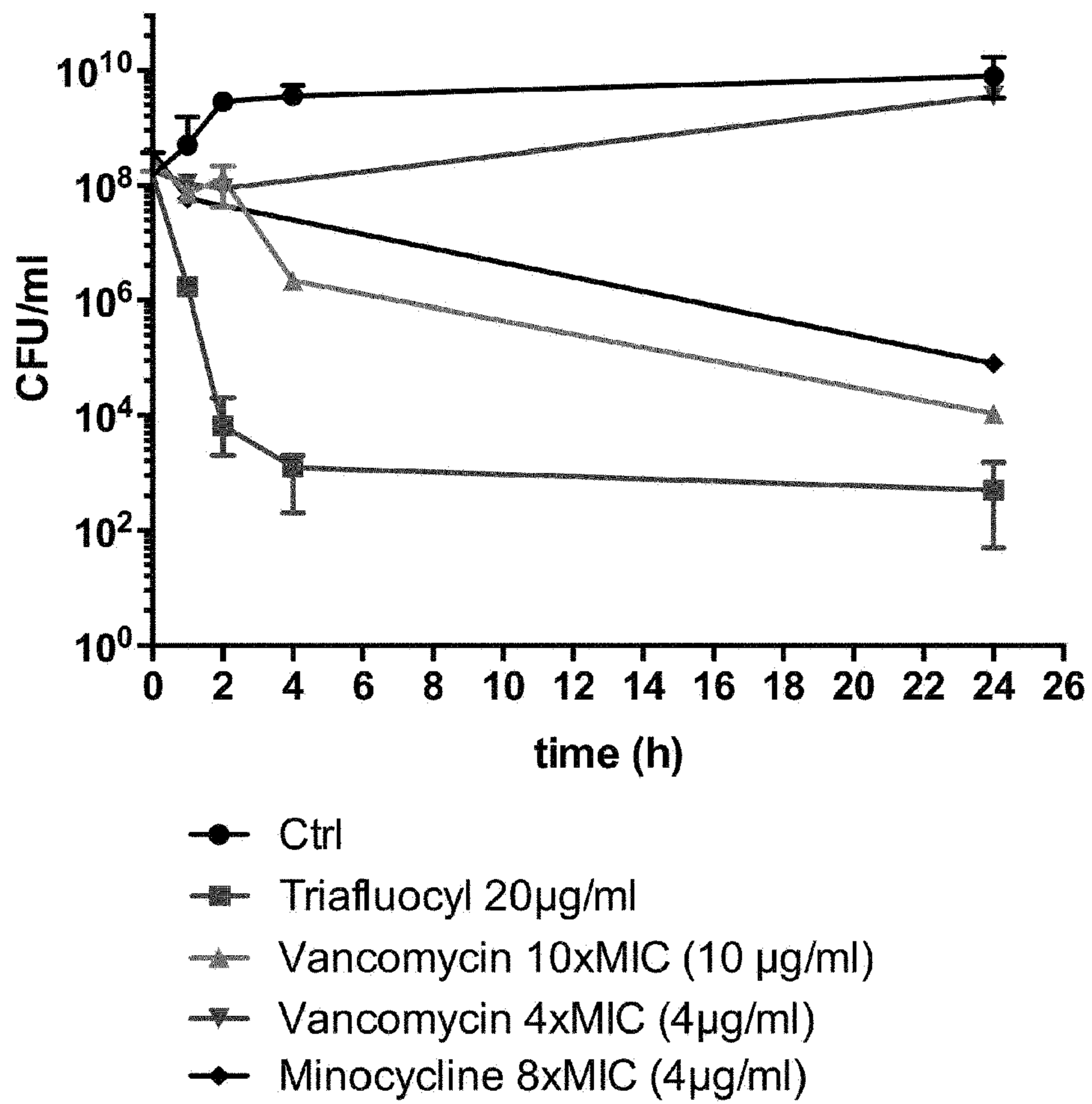
S. aureus MRSA

Figure 8A

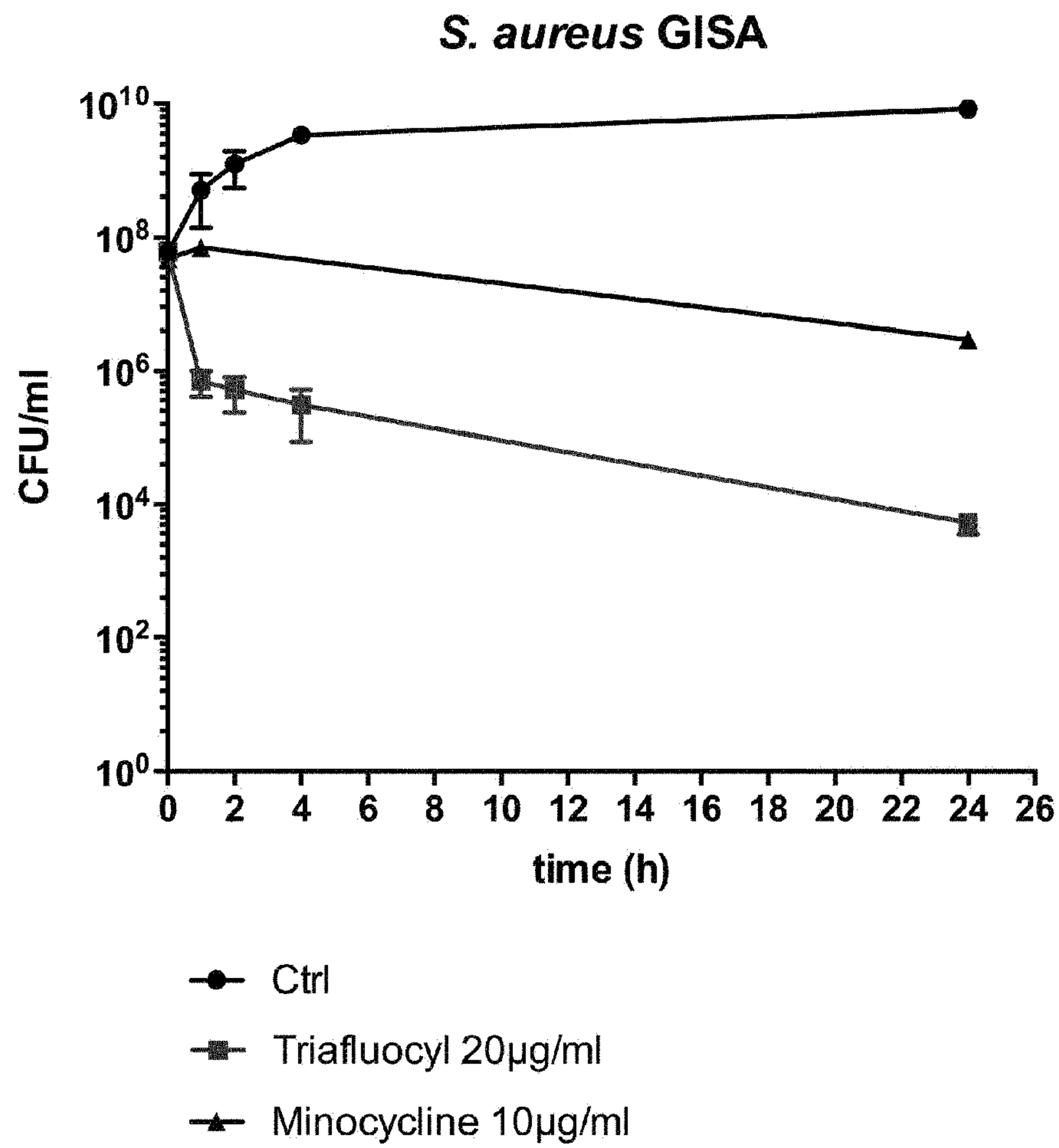


Figure 8B

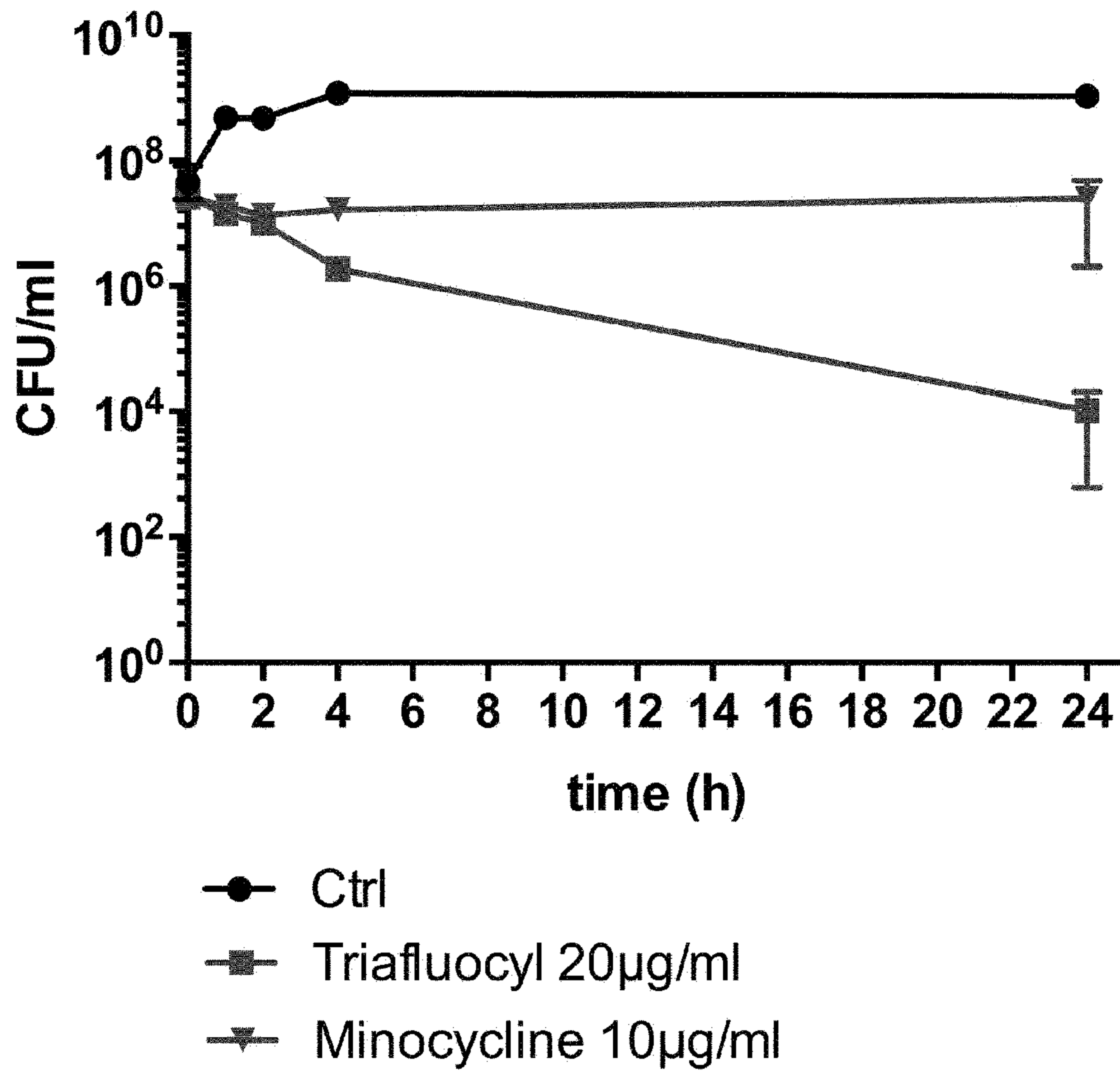
E.faecalis VRE

Figure 8C

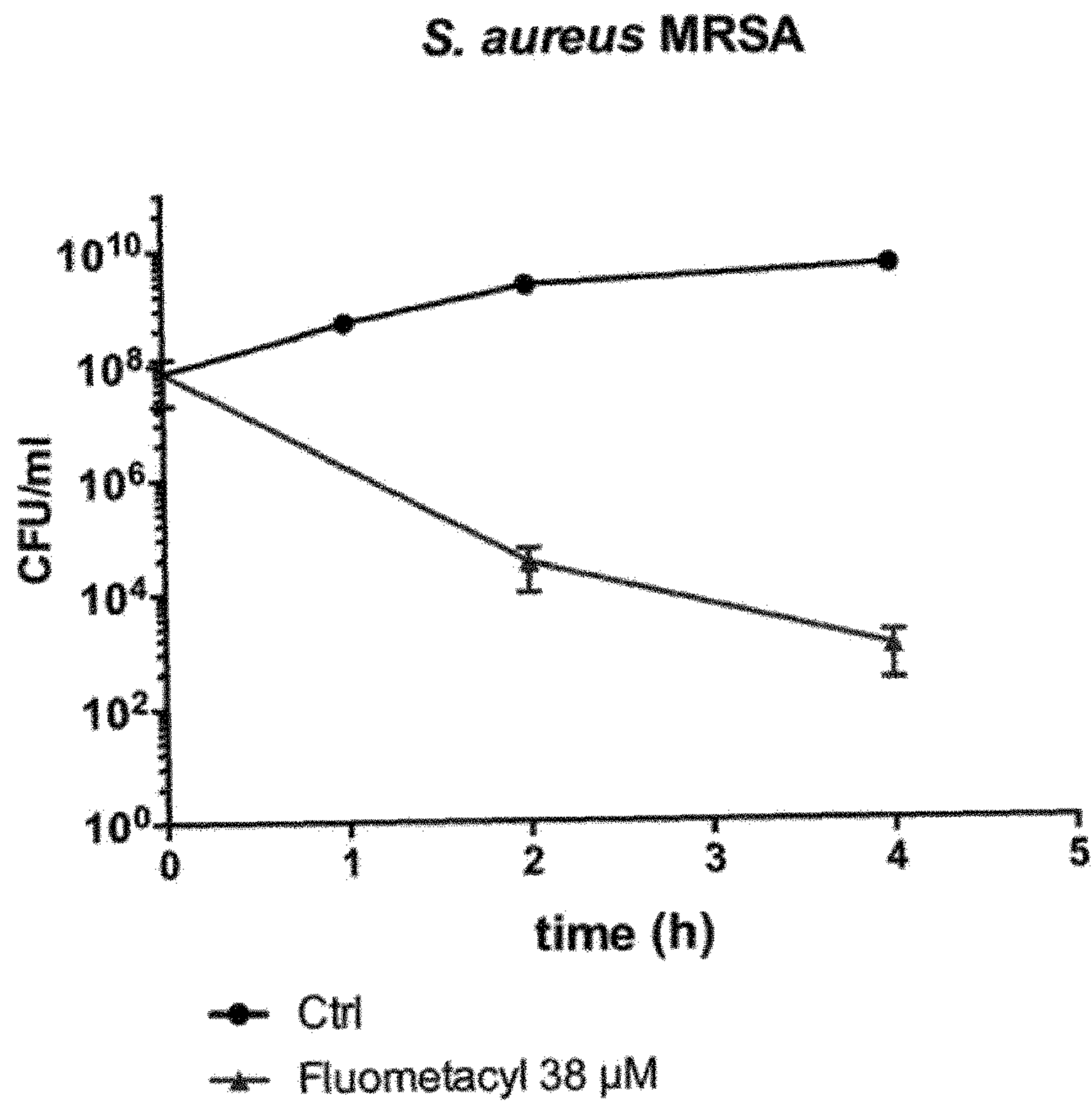


Figure 9

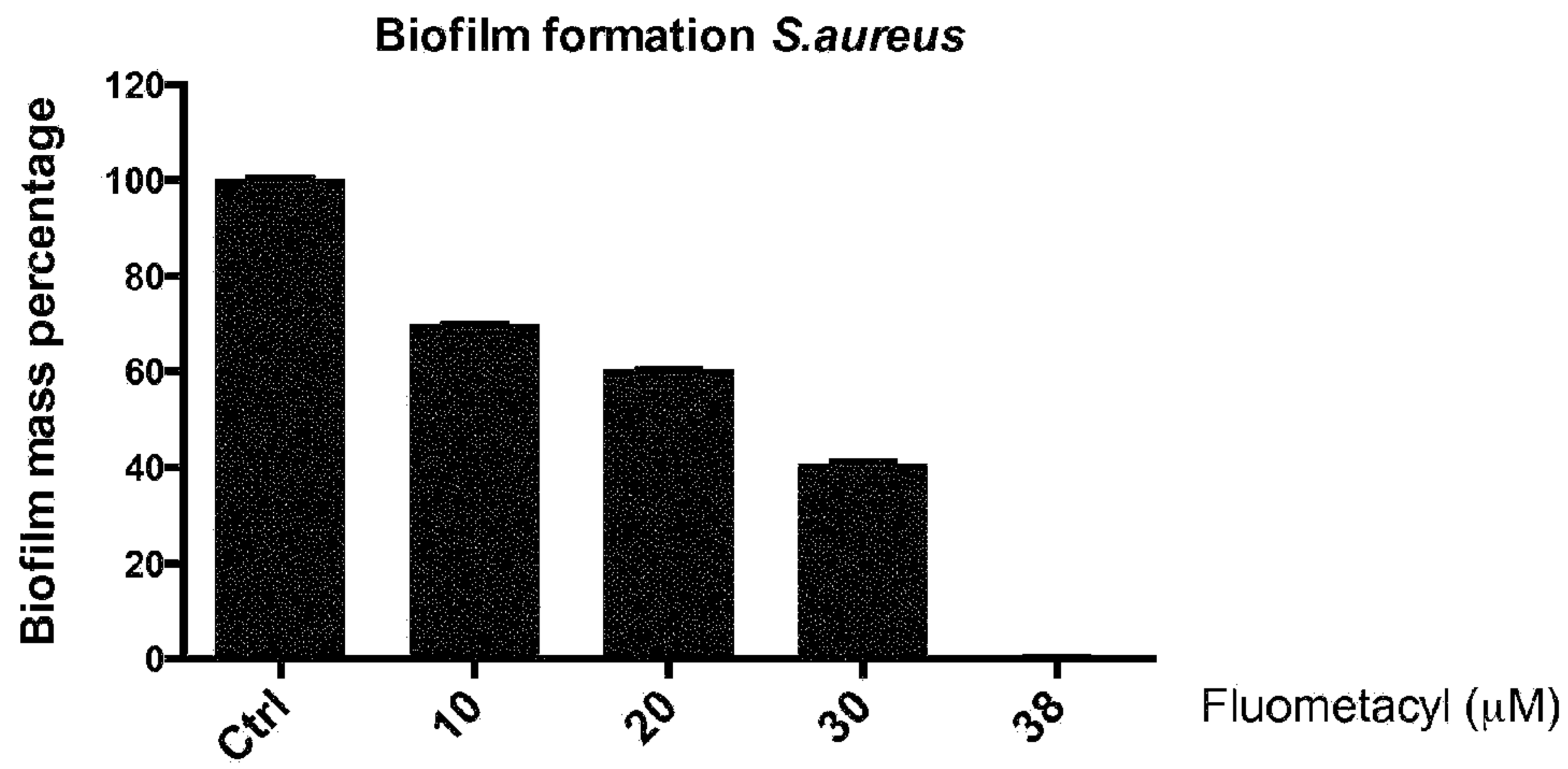


Figure 10 A

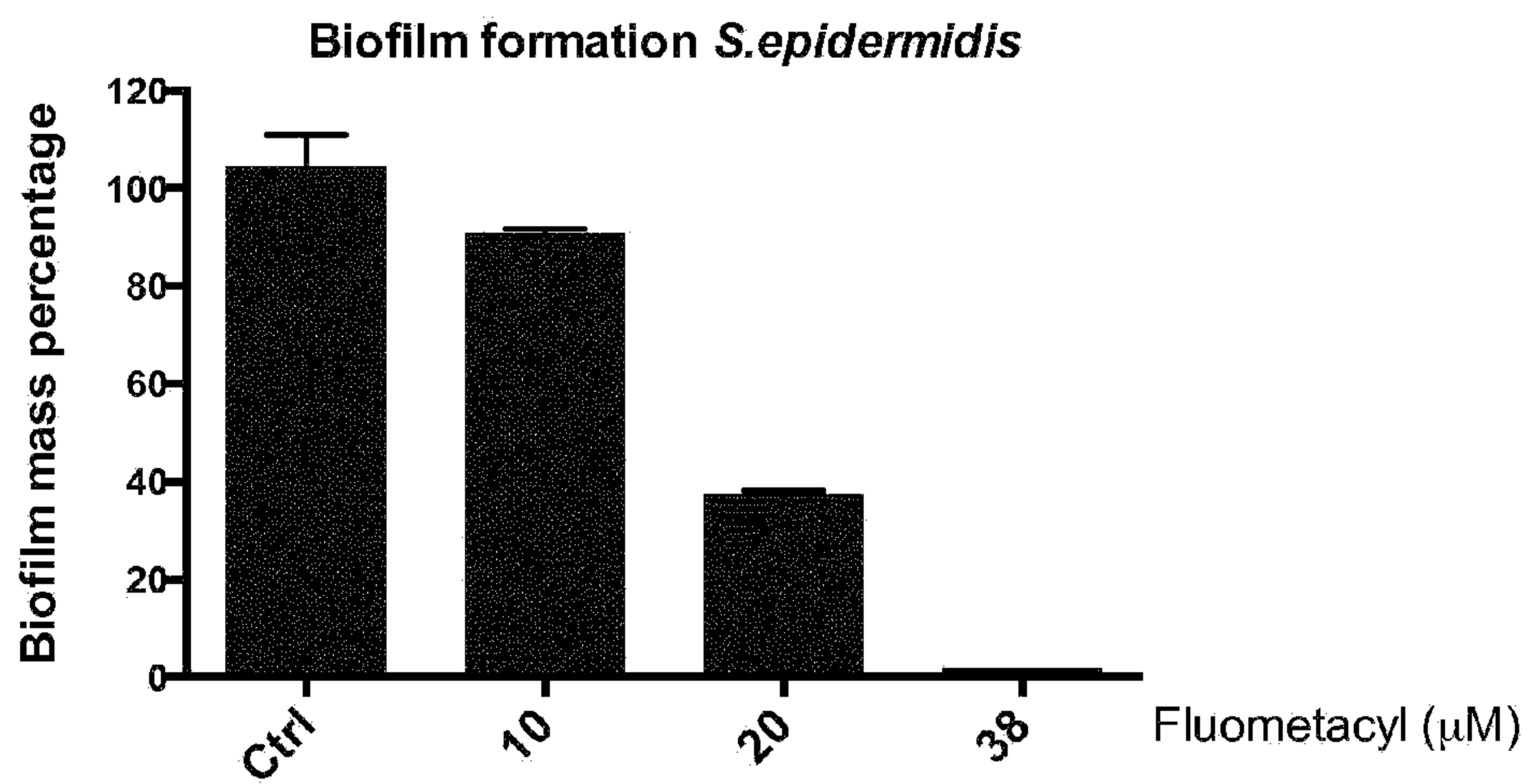


Figure 10B