

BAKUCHIOL DERIVATIVES, PHARMACEUTICALLY ACCEPTABLE SALTS THEREOF, AND PREPARATION METHOD AND USE OF THE SAME

TECHNICAL FIELD

The disclosure relates to the technical field of medicinal chemistry, in particular to bakuchiol derivatives, pharmaceutically acceptable salts thereof, and a preparation method and use of the same.

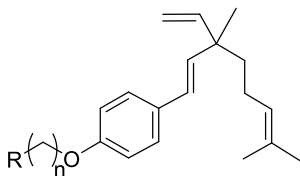
BACKGROUND

At present, infectious diseases have become the main cause of human death in the world, and multidrug-resistant bacteria are one of the most common causes of infection death. Antibiotic resistance of bacteria along with a sharp increase in morbidity and mortality and expensive treatment costs poses a serious threat to the global public health system. The World Health Organization and many countries have realized that the problem of antibiotic resistance will seriously hinder the control of infectious diseases and endanger human health. However, most pharmaceutical companies have greatly reduced their investment in the research and development of antibacterial agents since the antibacterial agents have a short medication cycle and drug resistance can be easily produced. In the past two decades, the number of approved new antibacterial agents has decreased drastically, especially of those based on new molecular entities. Therefore, there is an urgent need to develop a new antibacterial agent with high efficiency and low toxicity, which can effectively overcome the generation of drug resistance.

SUMMARY

Based on this, it is necessary to provide a bakuchiol derivative, a pharmaceutically acceptable salt thereof, and a preparation method and use of the same.

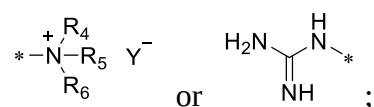
Provided are a bakuchiol derivative and a pharmaceutically acceptable salt thereof. The bakuchiol derivative has a structure shown in formula (I):



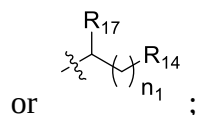
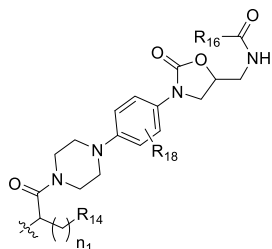
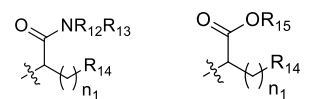
(I)

where n is an integer from 1 to 16;

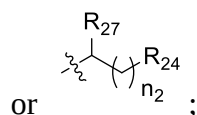
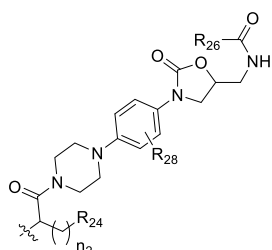
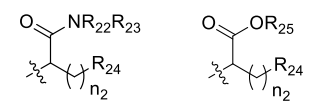
R is selected from halogens, $-\text{CONR}_1\text{R}_2$, $-\text{COOR}_3$, $-\text{NR}_4\text{R}_5$,



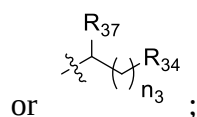
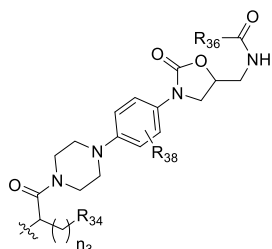
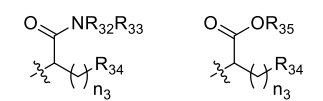
R_1 and R_2 are each independently selected from: $-\text{H}$,



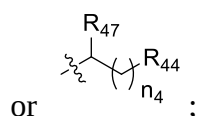
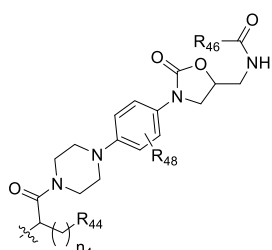
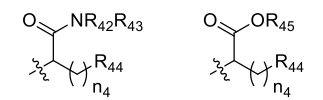
R_{12} and R_{13} are each independently selected from: $-\text{H}$,



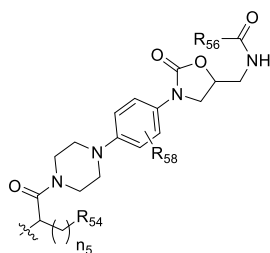
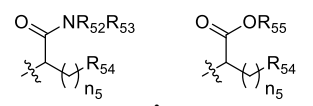
R_{22} and R_{23} are each independently selected from: $-\text{H}$,



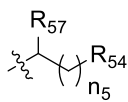
R_{32} and R_{33} are each independently selected from: $-\text{H}$,



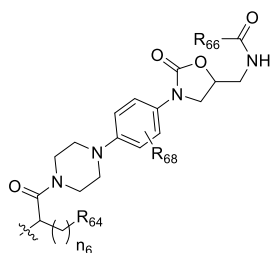
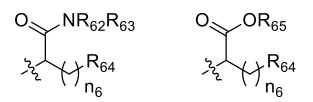
R₄₂ and R₄₃ are each independently selected from: -H,



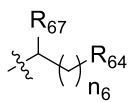
or



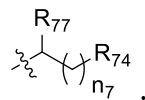
R₅₂ and R₅₃ are each independently selected from: -H,



or

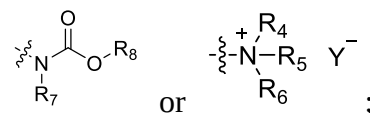


R₆₂ and R₆₃ are each independently selected from: -H or



where R₁₄, R₂₄, R₃₄, R₄₄, R₅₄, R₆₄ and R₇₄ are each independently selected from: -H, guanidyl,

-NR₄R₅, -SR₄, 5- to 20-membered nitrogen-containing heteroaryl,



R₁₅-R₁₇, R₂₅-R₂₇, R₃₅-R₃₇, R₄₅-R₄₇, R₅₅-R₅₇ and R₆₅-R₆₇ are each independently selected from:

-H or C₁₋₆ alkyl;

R₁₈, R₂₈, R₃₈, R₄₈, R₅₈ and R₆₈ are each independently selected from: -H, C₁₋₆ alkyl or halogen;

each of n₁, n₂, n₃, n₄, n₅, n₆ and n₇ is independently 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10;

R₇₇ is selected from: -H or C₁₋₆ alkyl;

R₃ is selected from: -H or C₁₋₄ alkyl;

R₄ and R₅ are each independently selected from: -H, C₁₋₁₆ alkyl, COOR₈, -Fmoc or R_a-substituted C₁₋₁₆ alkyl; or R₄ and R₅ together with N linked thereto may form a 5- to 20-membered heterocyclic ring, a 5- to 20-membered heteroaromatic ring, a 5- to 20-membered heterocyclic ring substituted by R_b or a 5- to 20-membered heteroaromatic ring substituted by R_b;

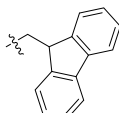
R_a is selected from: 5- to 10-membered aryl, 5- to 10-membered heteroaryl, -NR_{a1}R_{a2} or -SR_{a3};

R_b is selected from: C_{1-10} alkyl, $-(CH_2)_pNR_{b1}R_{b2}$ or $-SR_{b3}$, where p is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10;

each of R_{a1} , R_{a2} , R_{b1} and R_{b2} is independently -H, C_{1-10} alkyl or R_c -substituted C_{1-10} alkyl; or R_{a1} and R_{a2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring; or R_{b1} and R_{b2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring;

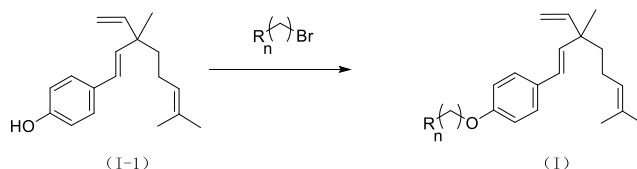
each of R_{a3} and R_{b3} is independently C_{1-10} alkyl;

R_c is selected from: $-NR_{c1}R_{c2}$, guanidyl or 5- to 6-membered nitrogen-containing heteroaryl, where each of R_{c1} and R_{c2} is independently: -H, C_{1-4} alkyl; or R_{c1} and R_{c2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring;

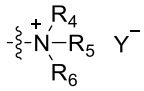
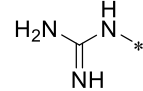
R_6 is C_{1-4} alkyl; R_7 is selected from: -H or C_{1-4} alkyl; R_8 is -H, C_{1-6} alkyl or ; and

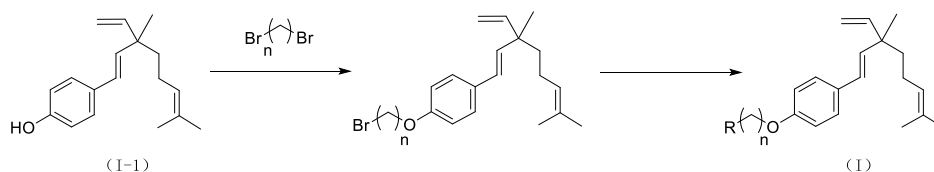
Y^- is an anion.

Provided is a preparation method of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof. When R is a halogen, the preparation method includes the following step:



reacting a compound shown in formula (I-1) with R_nBr , to obtain a compound shown in formula (I) with R being a halogen;

when R is NR_4R_5 ,  Y^- or , the preparation method includes the following steps:

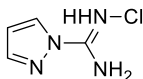


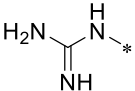
reacting a compound shown in formula (I-1) with Br_nBr , to obtain an intermediate with R being Br ;

reacting the intermediate with R being Br with HNR_4R_5 , to obtain a compound shown in formula (I) with R being NR_4R_5 ;

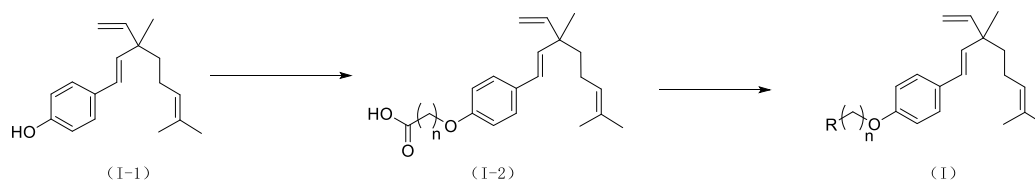
reacting the compound shown in formula (I) with R being NR_4R_5 with haloalkyl, to obtain a

compound shown in formula (I) with R being $\text{N}^+\text{R}_4\text{R}_5\text{R}_6 \text{ Y}^-$; and

reacting a compound shown in formula (I) with R being NH_2 with , to obtain a

compound shown in formula (I) with R being ; and

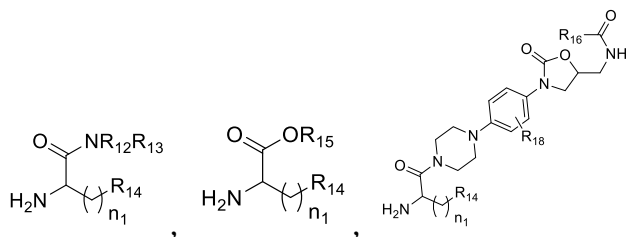
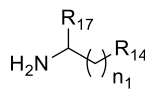
when R is selected from CONR_1R_2 and $-\text{COOR}_3$, the preparation method includes the following steps:



performing a condensation reaction on a compound shown in formula (I-1) and an alkyl bromoalkylate, to obtain a compound shown in formula (I) with R being $-\text{COOR}_3$;

hydrolyzing to obtain a compound shown in formula (I-2); and

performing a condensation reaction on the compound shown in formula (I-2) and

, or , to obtain a compound shown in formula (I) with R being CONR_1R_2 .

Provided is a pharmaceutical composition including at least one of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable excipient.

Provided is use of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition in preparation of antibacterial agents.

Provided is use of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition in preparation of drugs for treating or preventing diseases caused by bacterial infection.

Provided is use of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition in preparation of drugs for treating or preventing infectious diseases.

Provided is a method for treating or preventing bacterial infection, including administration of an effective amount of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition.

The disclosure designs and synthesizes a series of amphiphilic antibacterial compounds based on bakuchiol, which have comparatively excellent antibacterial activity. Specifically, the bakuchiol derivatives and pharmaceutically acceptable salts thereof exhibit excellent antibacterial activity on both Gram-positive bacteria (including methicillin-resistant *Staphylococcus aureus*) and Gram-negative bacteria, have good water solubility, show comparatively low cytotoxicity and hemolytic activity on mammalian cells, possess comparatively high membrane selectivity and comparatively favorable druggability, and could overcome the generation of drug resistance of bacteria in drug resistance research simulated in a laboratory.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a graph showing drug resistance of *S. aureus* ATCC29213 to a compound **60** and norfloxacin; and

FIG. 2 is a bar graph showing *in vivo* antibacterial efficacy of the compound **60** in a mouse model of cornea infection caused by *S. aureus* ATCC29213.

DETAILED DESCRIPTION

In order to facilitate the understanding of the disclosure, the disclosure will be described more comprehensively below, and preferred embodiments of the disclosure will be given. However, the disclosure may be embodied in many different forms, and is not limited to the embodiments described herein. On the contrary, these embodiments are provided to make the understanding of the disclosure of the disclosure more thorough and comprehensive.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by those skilled in the technical field of the disclosure. The terms used in the description of the disclosure herein are only for the purpose of describing specific embodiments, and are not intended to limit the disclosure. As used herein, the term "and/or" includes any and all combinations of one or more related listed items.

Explanation of terms

Definitions and general terms

Unless stated to the contrary, the following terms used in the description and claims have the following meanings.

In the disclosure, the term "optionally substituted by one or more substituents" means being substituted by one or more substituents, or unsubstituted. Specifically, "optional" or "optional" means that an event or environment described subsequently may but does not have to occur, and this description includes occasions when the event or environment occurs or does not occur. For example, "C₁₋₁₆ alkyl is optionally substituted by one or more hydroxyl groups" means that hydroxyl groups may but do not have to exist, and this description includes a situation in which C₁₋₁₆ alkyl is substituted by hydroxyl groups and a situation in which C₁₋₁₆ alkyl is not substituted by hydroxyl groups.

In the disclosure, "may form a ring together with ..." indicates that this situation may or may not occur. For example, R_{a1} and R_{a2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring, indicating that R_{a1} and R_{a2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring and may not form a 5- to 10-membered heterocyclic ring.

"Alkyl" refers to a saturated aliphatic hydrocarbon group, including straight-chain and branched-chain groups. C₁₋₁₆ alkyl refers to an alkyl group containing 1 to 16 carbon atoms. Non-limiting examples of alkyl in the disclosure include: methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl, sec-butyl, n-pentyl, 1,1-dimethylpropyl, 1,2-dimethylpropyl, 2,2-dimethylpropyl, 1-ethylpropyl, 2-methylbutyl, 3-methylbutyl, n-hexyl, 1-ethyl-2-methylpropyl, 1,1,2-trimethylpropyl, 1,1-dimethylbutyl, 1,2-dimethylbutyl, 2,2-dimethylbutyl, 1,3-dimethylbutyl, 2-ethylbutyl, 2-methylpentyl, 3-methylpentyl, 4-methylpentyl and 2,3-dimethylbutyl. C_{1-C4} alkyl refers to an alkyl group containing 1 to 4 carbon atoms. In an embodiment, C_{1-C4} alkyl is methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, tert-butyl and sec-butyl. Alkyl may be substituted or unsubstituted, and when it is substituted, a substituent may be substituted at any available point of attachment.

The term "alkoxy" refers to a group having -O-alkyl, i.e. an alkyl group as defined above attached to a parent nucleus structure via an oxygen atom. Suitable examples of phrases containing this term include, but not limited to, methoxy (-O-CH₃ or -OMe), ethoxy (-O-CH₂CH₃ or -OEt) and tert-butoxy (-O-C(CH₃)₃ or -OtBu).

"Heterocyclyl" refers to a saturated or partially unsaturated monocyclic or polycyclic cyclic hydrocarbon substituent, i.e. a ring moiety in which one or more ring atoms are selected from

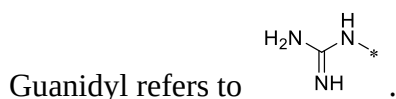
heteroatoms such as nitrogen, oxygen or $S(O)_m$ (where m is an integer from 0 to 2), preferably nitrogen or oxygen heteroatoms, but excluding -O-O-, -O-S- or -S-S-; and the remaining ring atoms are carbon. 5- to 20-membered heterocyclyl refers to a ring containing 5 to 20 ring atoms, at least one of which is a heteroatom. Preferably, the heterocyclyl ring contains 5 to 6 ring atoms, of which 1 to 2 are heteroatoms. In an embodiment, heterocyclyl is dihydrofuranyl, tetrahydrofuranyl, pyrrolidinyl, piperidinyl, piperazinyl, morpholinyl, thiomorpholinyl or homopiperazinyl, etc.

"Aryl" refers to an aromatic hydrocarbon group derived by removing a hydrogen atom on the basis of an aromatic ring compound, which may be monocyclic aryl, fused aryl or polycyclic aryl. For polycyclic ring species, at least one of them is an aromatic ring system. For example, 5- to 20-membered aryl refers to an aryl group having 5 to 20 ring atoms, and the aryl group is optionally further substituted. Suitable examples of "aryl" in the disclosure include, but not limited to, benzene, biphenyl, naphthalene, anthracene, phenanthrene, perylene, triphenylene and derivatives thereof. It could be understood that a plurality of aryl groups interrupted by short non-aromatic units (for example, < 10% of non-H atoms, such as C, N or O atoms), specifically such as acenaphthene, fluorene, or 9,9-diarylfluorene, triarylamine and diarylether systems, should also be included in the definition of aryl.

"Heteroaryl" means that at least one carbon atom is replaced by a non-carbon atom on the basis of aryl, and the non-carbon atom may be a N atom, an O atom, a S atom, etc. For example, "5- to 20-membered heteroaryl" refers to a heteroaryl group having 5 to 20 ring atoms, and the heteroaryl group is optionally further substituted. Suitable examples of "heteroaryl" in the disclosure include, but not limited to, furan, benzofuran, thiophene, benzothiophene, pyrrole, pyrazole, triazole, imidazole, oxazole, oxadiazole, thiazole, tetrazole, indole, carbazole, pyrroloimidazole, pyrrolopyrrole, thienopyrrole, thienothiophene, furopyrrole, furofuran, thienofuran, benzisoxazole, benzisothiazole, benzimidazole, pyridine, pyrazine, pyridazine, pyrimidine, triazine, quinoline, isoquinoline, cinnoline, quinoxaline, phenanthridine, perimidine, quinazoline and quinazolinone.

"Amino" refers to a derivative of ammonia, having structural characteristics of a formula $-N(X)_2$, where each "X" is independently H, substituted or unsubstituted alkyl, substituted or unsubstituted cycloalkyl, substituted or unsubstituted heterocyclyl, etc. Non-limiting types of amino include $-NH_2$, $-N(alkyl)_2$, $-NH(alkyl)$, $-N(cycloalkyl)_2$, $-NH(cycloalkyl)$, $-N(heterocyclyl)_2$, $-NH(heterocyclyl)$, $-N(aryl)_2$, $-NH(aryl)$, $-N(alkyl)(aryl)$, $-N(alkyl)(heterocyclyl)$, $-N(cycloalkyl)(heterocyclyl)$, $-N(aryl)(heteroaryl)$, $-N(alkyl)(heteroaryl)$, etc.

"Halogen" or "halo" refers to F, Cl, Br or I.



In the disclosure, when the configuration of chiral carbon atoms is not indicated, it should be understood as including any configuration acceptable in the art.

The compounds of the disclosure can exist in non-solvated forms and solvated forms containing pharmaceutically acceptable solvents (such as water, ethanol, etc.), that is, both solvated and non-solvated forms are included.

In the disclosure, a single bond interrupted by a wave “” represents an attachment position.

For example, means that carbon at the 2-position of propane is a site of attachment, and

means that N is a site of attachment. In the disclosure, * denotes a site of attachment.

In the disclosure, a certain substitutable site may be substituted by one or more substituents, and when there are a plurality of substituents for this substitutable site, the plurality of substituents may be the same as or different from each other.

A "pharmaceutical composition" denotes a mixture containing one or more of the compounds described herein or physiologically/pharmaceutically acceptable salts thereof or prodrugs and other chemical components, as well as additional components, such as physiologically/pharmaceutically acceptable carriers and excipients. The purpose of the pharmaceutical composition is to promote the administration to organisms, facilitate the absorption of active ingredients and further exert biological activity.

The excipients contained in the composition may be one or more buffers, stabilizers, anti-sticking agents, surfactants, wetting agents, lubricants, emulsifiers, adhesives, suspending agents, disintegrating agents, fillers, adsorbents, coating, (intestinal or slow-release) preservatives, antioxidants, opaquing agents, glidants, processing aids, colorants, sweeteners, perfuming agents, flavoring agents and other known additives.

"Pharmaceutically acceptable salt" refers to an organic or inorganic salt of a pharmaceutically acceptable compound.

When the compound is acidic or includes bioelectronic isotopes that are sufficiently acidic, appropriate "pharmaceutically acceptable salts" refer to salts prepared from pharmaceutically acceptable nontoxic bases including inorganic bases and organic bases. The salts are derived from inorganic bases containing aluminum, ammonium, calcium, copper, iron, lithium, magnesium,

manganese salts, manganese, potassium, sodium, zinc, etc. Specific examples include ammonium, calcium, magnesium, potassium and sodium salts. The salts are derived from pharmaceutically acceptable organic nontoxic bases. The organic nontoxic bases include salts of primary, secondary and tertiary amines, substituted amines including naturally occurring substituted amines, cyclic amines and basic ion exchange resins such as arginine, betaine, caffeine, choline, N,N'-dibenzylethylenediamine, ethylenediamine, 2-diethylaminoethanol, 2-dimethylaminoethanol, ethanolamine, ethylenediamine, N-ethylmorpholine, N-ethylhexahydropyridine, reduced glucosamine, glucosamine, histidine, hydrabamine, isopropylamine, lysine, meglumine, morpholine, piperazine, piperidine, polyamine resin, procaine, purine, theobromine, triethylamine, trimethylamine, tripropylamine, tromethamine and the like.

When the compound is basic or includes bioelectronic isotopes that are sufficiently basic, salts may be prepared from pharmaceutically acceptable nontoxic acids including inorganic and organic acids. Such acids include acetic acid, benzenesulfonic acid, benzoic acid, camphorsulfonic acid, citric acid, ethanesulfonic acid, fumaric acid, gluconic acid, hydrobromic acid, hydrochloric acid, hydroxyethylsulfonic acid, lactic acid, maleic acid, malic acid, amygdalic acid, methanesulfonic acid, mucic acid, nitric acid, pamoic acid, pantothenic acid, phosphoric acid, sulfuric acid, succinic acid, tartaric acid, p-toluenesulfonic acid and the like. Specific examples include citric acid, hydrobromic acid, hydrochloric acid, phosphoric acid, sulfuric acid, maleic acid and tartaric acid. Other exemplary salts include, but not limited to, sulfate, citrate, acetate, oxalate, chloride, bromide, iodide, nitrate, sulfite, phosphate, superphosphate, isonicotinic acid, lactic acid, salicylate, acid citrate, tartrate, oleate, tannate, pantothenate, bitartrate, ascorbate, succinate, fumarate, maleate, gentisate, gluconate, glucuronate, saccharate, formate, benzoate, glutamate, methanesulfonate, ethanesulfonate, benzenesulfonate, p-toluenesulfonate and pamoate (for example, 1,1'-methylene-bis-(2-hydroxy-3-naphthoate)).

In addition, pharmaceutical preparations containing the compounds may be tablets, capsules, oral liquids, pills, granules, powders, ointments, patches, suppositories, buccal tablets, eye drops, eye ointments, ear drops, sprays, aerosols, inhalants, injections, etc.

The term "therapeutically effective amount" refers to the amount of an effective compound or pharmaceutical agent, which is the minimum amount necessary to improve, cure or treat one or more symptoms of a disease or disorder.

In addition, the compound and the pharmaceutical composition of the disclosure may be administered alone or in combination with other drugs. For combined therapy with more than one

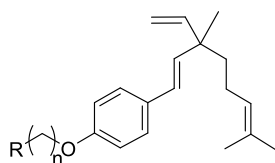
active agent, when the active agent exists in divided doses of a preparation, the active agent may be administered individually or in combination. In addition, the administration of one drug may be performed before, at the same time of or after the administration of another drug. During the administration in combination with other drugs, the "effective amount" of a second drug will depend on the type of drug being used.

The compound or the pharmaceutical composition of the disclosure may also be included in a kit.

It should be noted that the agent whose specific source is not indicated in the disclosure is a conventional one available in the market.

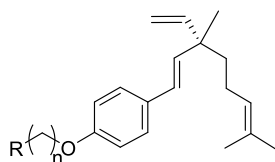
Detailed Description

An embodiment of the disclosure provides a bakuchiol derivative and a pharmaceutically acceptable salt thereof, having a structure shown in formula (I):



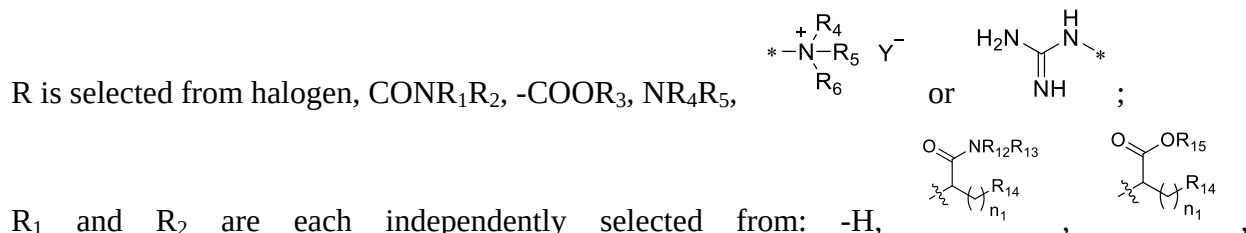
(I).

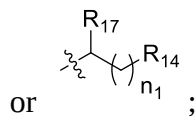
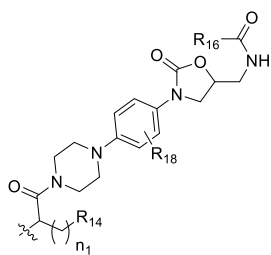
Further, the bakuchiol derivative and a pharmaceutically acceptable salt thereof have a structure shown in formula (I'):



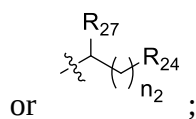
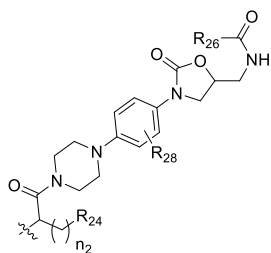
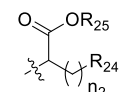
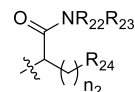
(I'),

where n is an integer from 1 to 16. In an embodiment, n is 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 or 12;

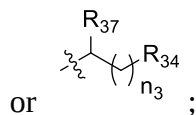
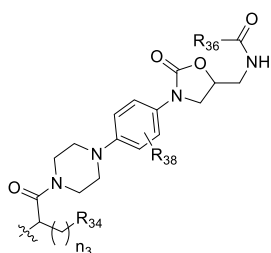
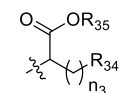
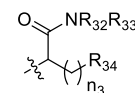




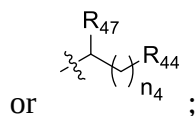
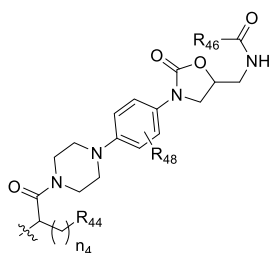
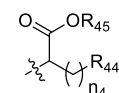
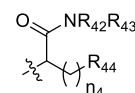
R_{12} and R_{13} are each independently selected from: -H,



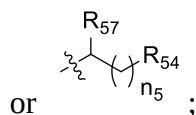
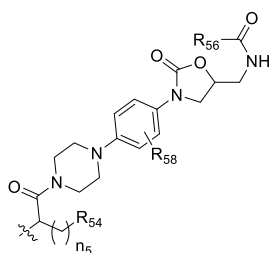
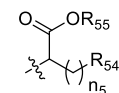
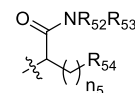
R_{22} and R_{23} are each independently selected from: -H,



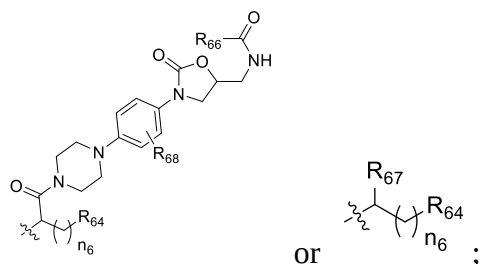
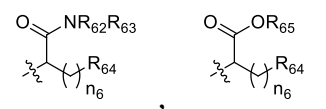
R_{32} and R_{33} are each independently selected from: -H,



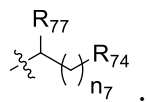
R_{42} and R_{43} are each independently selected from: -H,



R_{52} and R_{53} are each independently selected from: -H,



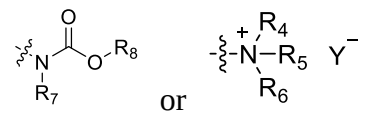
or



R_{62} and R_{63} are each independently selected from: -H or

where R_{14} , R_{24} , R_{34} , R_{44} , R_{54} , R_{64} and R_{74} are each independently selected from: -H, guanidyl,

- NR_4R_5 , - SR_4 , 5- to 20-membered nitrogen-containing heteroaryl,



R_{15} - R_{17} , R_{25} - R_{27} , R_{35} - R_{37} , R_{45} - R_{47} , R_{55} - R_{57} and R_{65} - R_{67} are each independently selected from:

-H or C_{1-6} alkyl;

R_{18} , R_{28} , R_{38} , R_{48} , R_{58} and R_{68} are each independently selected from: -H, C_{1-6} alkyl or halogen;

each of n_1 , n_2 , n_3 , n_4 , n_5 , n_6 and n_7 is independently 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10;

R_{77} is selected from: -H or C_{1-6} alkyl;

R_3 is selected from: -H or C_{1-4} alkyl;

R_4 and R_5 are each independently selected from: -H, C_{1-16} alkyl, $COOR_8$, -Fmoc or R_a -substituted C_{1-16} alkyl; or R_4 and R_5 together with N linked thereto may form a 5- to 20-membered heterocyclic ring, a 5- to 20-membered heteroaromatic ring, a 5- to 20-membered heterocyclic ring substituted by R_b or a 5- to 20-membered heteroaromatic ring substituted by R_b ;

R_a is selected from: 5- to 10-membered aryl, 5- to 10-membered heteroaryl, - $NR_{a1}R_{a2}$ or - SR_{a3} ;

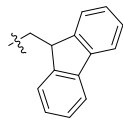
R_b is selected from: C_{1-10} alkyl, $-(CH_2)_pNR_{b1}R_{b2}$ or - SR_{b3} , where p is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10;

each of R_{a1} , R_{a2} , R_{b1} and R_{b2} is independently -H, C_{1-10} alkyl or R_c -substituted C_{1-10} alkyl; or R_{a1} and R_{a2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring; or R_{b1} and R_{b2} together with a N atom linked thereto may form a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring;

each of R_{a3} and R_{b3} is independently C_{1-10} alkyl;

R_c is selected from: - $NR_{c1}R_{c2}$, guanidyl or 5- to 6-membered nitrogen-containing heteroaryl, where each of R_{c1} and R_{c2} is independently: -H, C_{1-4} alkyl; or R_{c1} and R_{c2} together with a N atom

linked thereto may form a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring;

R_6 is C_{1-4} alkyl; R_7 is selected from: -H or C_{1-4} alkyl; R_8 is -H, C_{1-6} alkyl or ; and

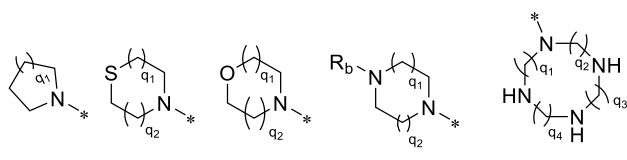
Y^- is an anion. Furthermore, Y^- is a halogen anion. Furthermore, Y^- is an iodide ion.

In the disclosure, bakuchiol used as a starting material is prepared into a series of amphiphilic cationic bakuchiol compounds. Bakuchiol contains a hydrophobic skeleton consisting of a benzene ring and an isopentenyl lipid chain, and has good antibacterial activity on gram-positive bacteria. By introducing different cationic groups into the molecular skeleton of bakuchiol, a series of cationic amphiphilic bakuchiol compounds may be synthesized as small molecular antibacterial peptide mimetics. Cationic groups introduced into bakuchiol derivatives may enhance the interaction between the bakuchiol derivatives and negatively charged bacterial cell membranes through electrostatic interaction, and its hydrophobic portions may be inserted into phospholipid bilayers of the bacterial cell membranes through hydrophobic interaction, thereby destroying the integrity of the bacterial cell membranes, leading to the leakage of cell contents and eventually leading to death of bacteria. the structure of the bakuchiol derivatives is systematically optimized to obtain a series of new antibacterial agents with high efficiency and low toxicity, which have membrane targeting or multi-targeting properties and could overcome the generation of drug resistance of bacteria.

Further, R_3 is selected from: H, methyl, ethyl or isopropyl.

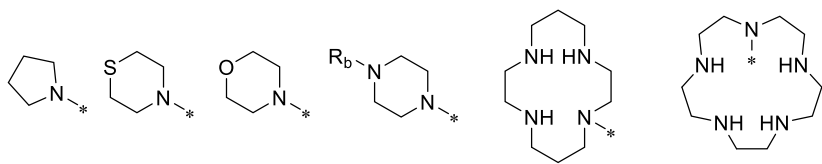
Further, R_4 and R_5 are each independently selected from: H, C_{1-12} alkyl, $COOR_8$, -Fmoc and R_a -substituted C_{1-12} alkyl; and R_4 and R_5 together with N linked thereto may form a 5- to 15-membered heterocyclic ring, a 5- to 10-membered heteroaromatic ring, a 5- to 15-membered heterocyclic ring substituted by R_b and a 5- to 15-membered heteroaromatic ring substituted by R_b . Further, R_4 and R_5 are each independently selected from: H, C_{1-10} alkyl, $COOR_8$, -Fmoc and R_a -substituted C_{1-10} alkyl; and R_4 and R_5 together with N linked thereto may form a 5- to 15-membered heterocyclic ring, a 5- to 10-membered heteroaromatic ring, a 5- to 15-membered heterocyclic ring substituted by R_b and a 5- to 15-membered heteroaromatic ring substituted by R_b .

Further, heterocyclyl is selected from the following structural groups:



where q_1, q_2, q_3 and q_4 are each independently selected from: 1, 2, 3 or 4.

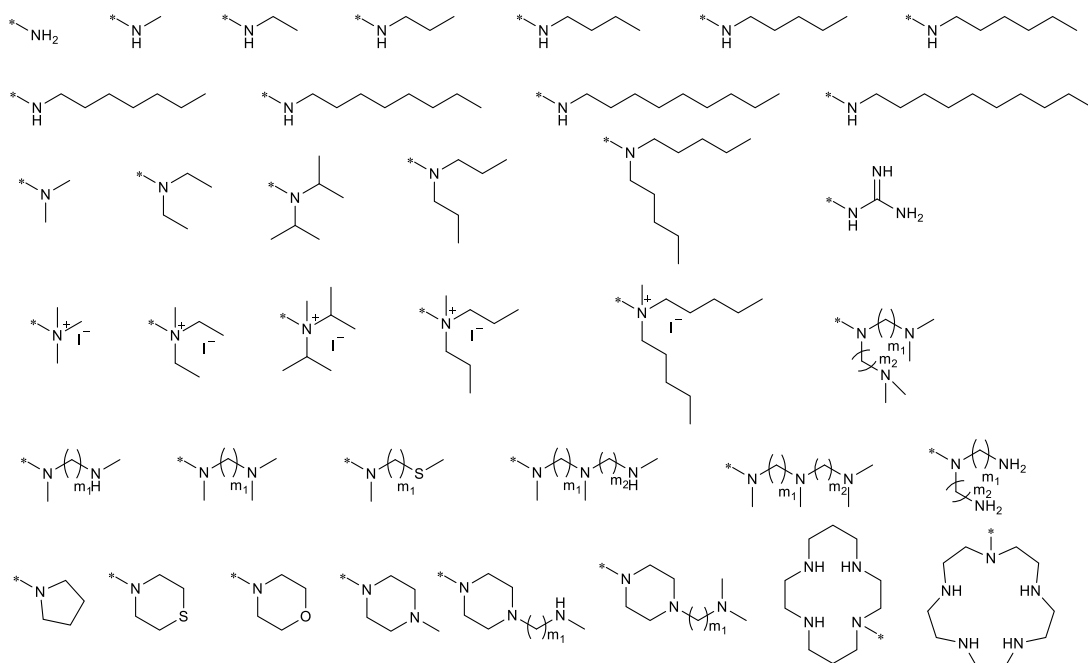
Furthermore, heterocyclyl is selected from:



Further, R_a is selected from pyridine, pyrimidine, triazine, -NR_{a1}R_{a2} or -SR_{a3}. Furthermore, R_a is selected from pyridine, -NR_{a1}R_{a2} or -SR_{a3}.

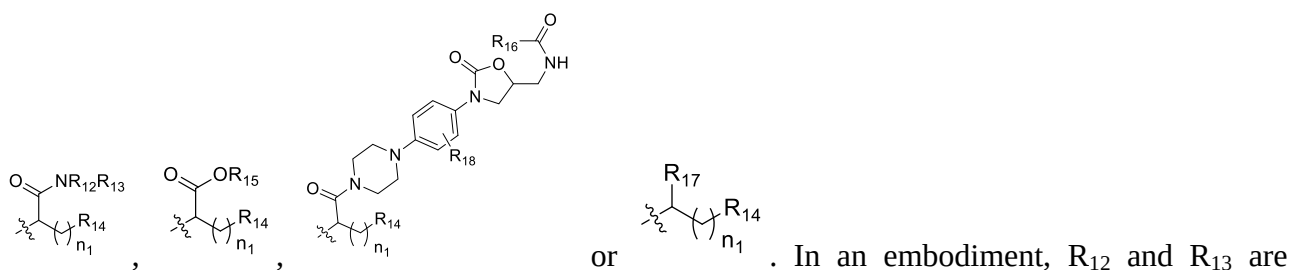
Further, each of R_{a1} and R_{a2} is independently H, C₁₋₄ alkyl or NR_{c1}R_{c2}-substituted C₁₋₄ alkyl. Further, R_{a3} is C₁₋₄ alkyl. Further, each of R_{c1} and R_{c2} is independently H or C₁₋₄ alkyl. Further, R_b is selected from H, C₁₋₆ alkyl or -(CH₂)_pNR_{b1}R_{b2}, where p is 0, 1, 2, 3, 4, 5 or 6. Furthermore, each of R_{b1} and R_{b2} is independently H or C₁₋₄ alkyl.

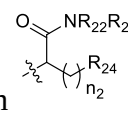
Further, R is selected from the following groups:

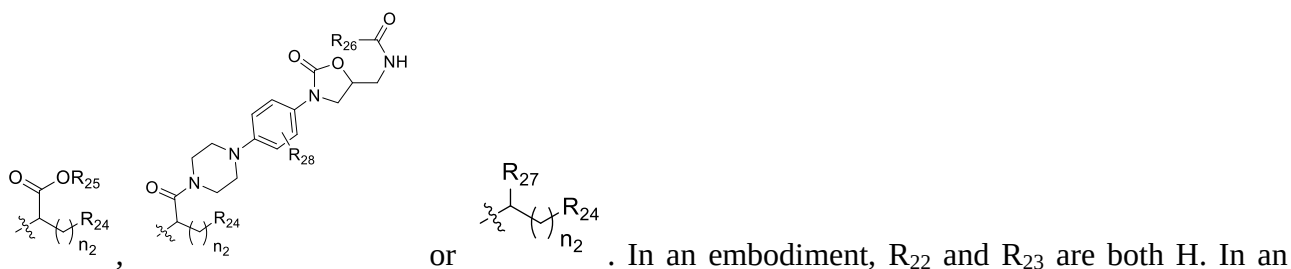


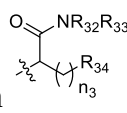
where each of m_1 and m_2 is independently 1, 2, 3, 4, 5, 6, 7 or 8.

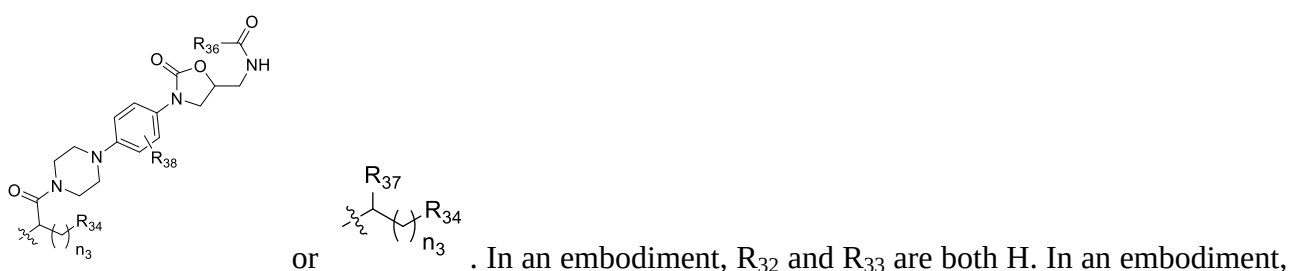
Further, R_1 and R_2 are not simultaneously H. Further, one of R_1 and R_2 is H, and another one is

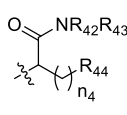


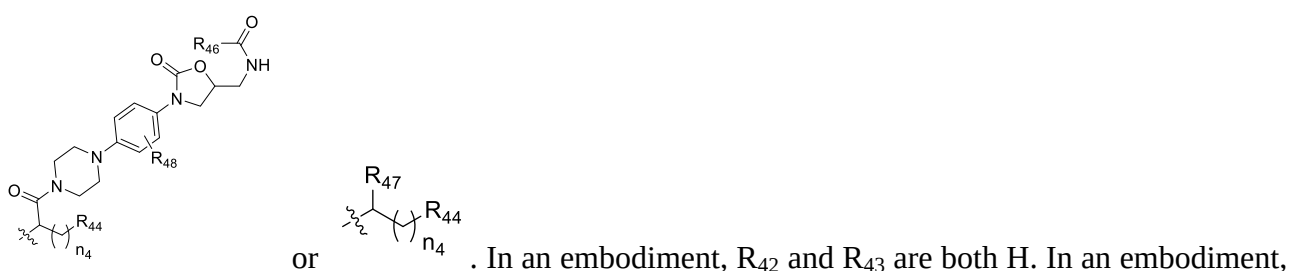
both H. In an embodiment, one of R₁₂ and R₁₃ is H, and another one is selected from ,

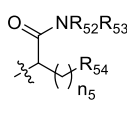


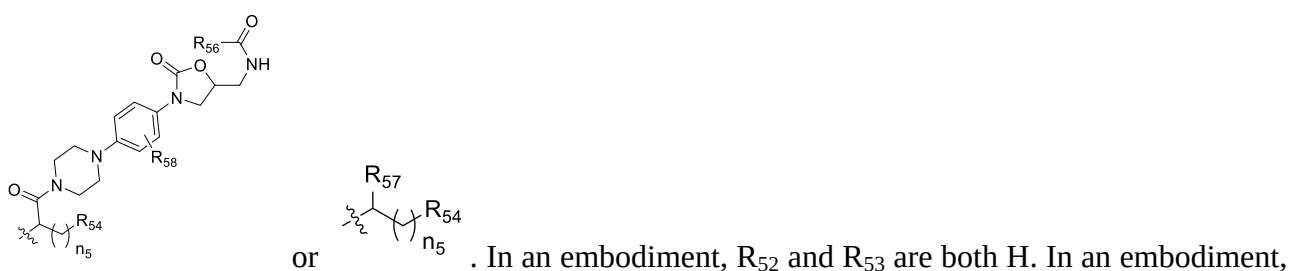
embodiment, one of R₂₂ and R₂₃ is H, and another one is selected from ,

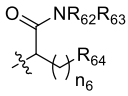
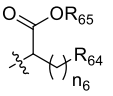
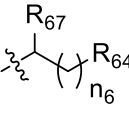


one of R₃₂ and R₃₃ is H, and another one is selected from ,

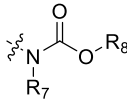
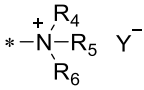


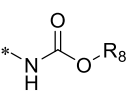
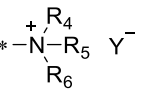
one of R₄₂ and R₄₃ is H, and another one is selected from ,

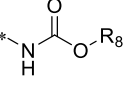
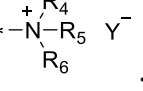


one of R_{52} and R_{53} is H, and another one is selected from ,  or .

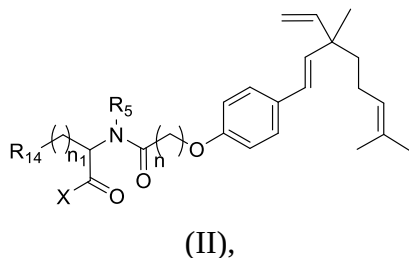
Further, R_{14} , R_{24} , R_{34} , R_{44} , R_{54} , R_{64} and R_{74} are each independently selected from: H, guanidyl,

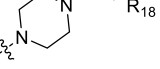
$-NR_4R_5$, $-SR_4$, 5- to 10-membered nitrogen-containing heteroaryl,  or . Further, R_{14} , R_{24} , R_{34} , R_{44} , R_{54} , R_{64} and R_{74} are each independently selected from H, guanidyl,

$-NR_4R_5$, $-SR_4$, 5-membered nitrogen-containing heteroaryl  or . Further, R_{14} , R_{24} , R_{34} , R_{44} , R_{54} , R_{64} and R_{74} are each independently selected from H, guanidyl, $-NR_4R_5$,

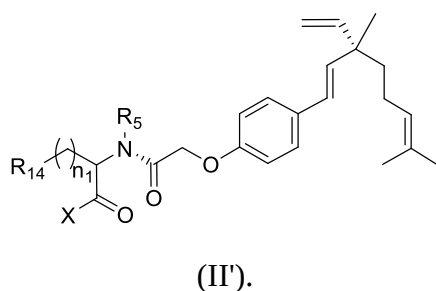
$-N(CH_3)_2$, $-SCH_3$, ,  or . Further, R_4 and R_5 are each independently selected from H or C_{1-4} alkyl. Furthermore, R_4 and R_5 are each independently selected from H, methyl, ethyl, propyl, isopropyl or butyl.

Further, the above bakuchiol derivative is selected from compounds of the following general formula:

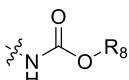


where X is $NR_{12}R_{13}$, OR_{15} or .

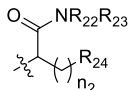
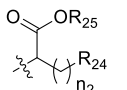
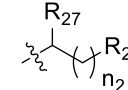
Further, the above bakuchiol derivative is selected from compounds of the following general formula:

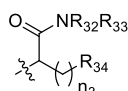
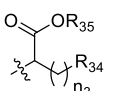
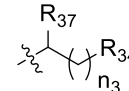


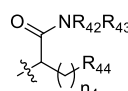
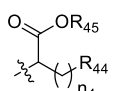
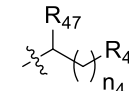
Further, in the above general formula (II) or formula (II'), X is OR_{15} , and R_{14} is selected from: H,

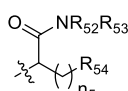
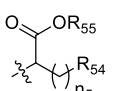
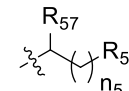
guanidyl, $-\text{NH}_2$, $-\text{SCH}_3$,  or . Further, in the above general formula (II) or formula (II'), X is $\text{NR}_{12}\text{R}_{13}$, and at least one of R_{14} , R_{24} , R_{34} , R_{44} , R_{54} , R_{64} and R_{74} is guanidyl.

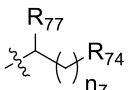
Further, in the above general formula (II) or formula (II'), X is $\text{NR}_{12}\text{R}_{13}$; one of R_{12} and R_{13} is H,

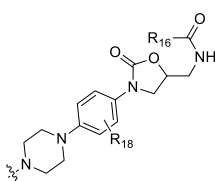
and another one is selected from ,  or ; one of R_{22} and R_{23} is H, and

another one is selected from ,  or ; one of R_{32} and R_{33} is H, and

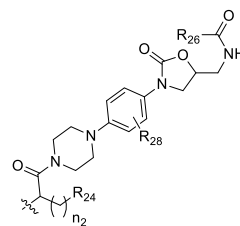
another one is selected from ,  or ; one of R_{42} and R_{43} is H, and

another one is selected from ,  or ; and one of R_{62} and R_{63} is H, and

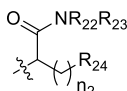
another one is selected from .

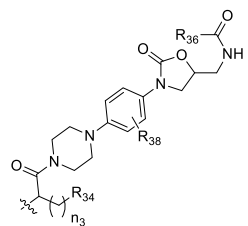
In an embodiment, in the above general formula (II) or formula (II'), X is .

In an embodiment, in the above general formula (II) or formula (II'), X is $\text{NR}_{12}\text{R}_{13}$; and one of

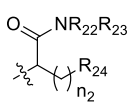
R_{12} and R_{13} is H, and another one is selected from .

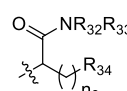
In an embodiment, in the above general formula (II) or formula (II'), X is $\text{NR}_{12}\text{R}_{13}$; one of R_{12}

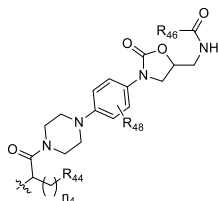
and R_{13} is H, and another one is selected from ; and one of R_{22} and R_{23} is H, and another

one is selected from .

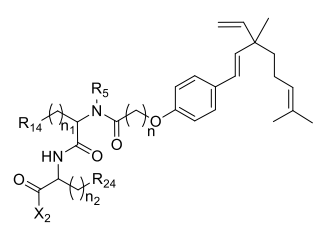
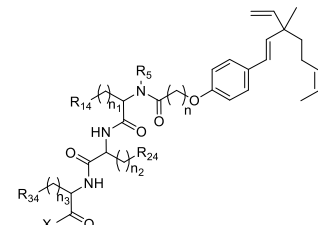
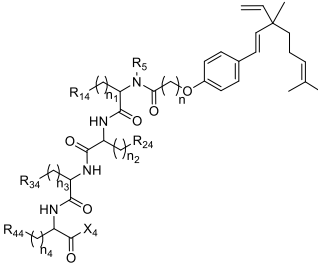
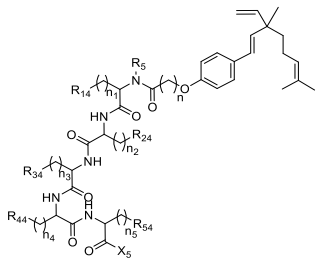
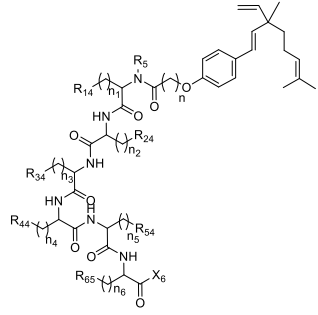
In an embodiment, in the above general formula (II) or formula (II'), X is $\text{NR}_{12}\text{R}_{13}$; one of R_{12}

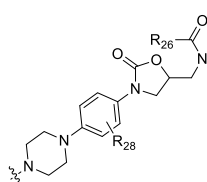
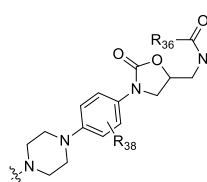
and R_{13} is H, and another one is selected from  ; one of R_{22} and R_{23} is H, and another one

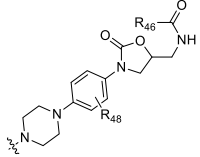
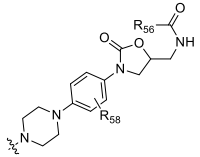
is selected from  ; and one of R_{32} and R_{33} is H, and another one is selected from

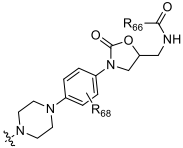


Further, the above bakuchiol derivative is selected from compounds of the following general formulae:

	
(III) ;	(IV)
	
(V)	(VI)
	
(VII)	

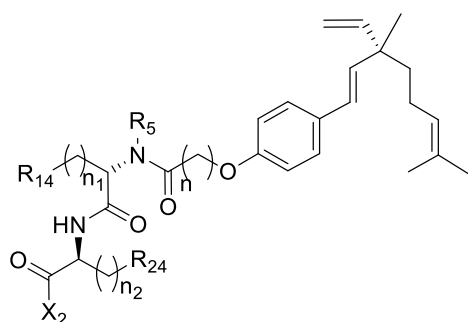
where X_2 is $NR_{22}R_{23}$, OR_{25} or  ; X_3 is $NR_{32}R_{33}$, OR_{35} or  ; X_4

is $\text{NR}_{42}\text{R}_{43}$, OR_{45} or ; X_5 is $\text{NR}_{52}\text{R}_{53}$, OR_{55} or ; and X_6 is $\text{NR}_{62}\text{R}_{63}$,

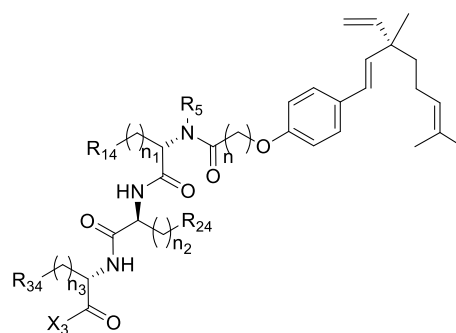
OR_{65} or .

Further, the above bakuchiol derivative is selected from compounds of the following general formulae:

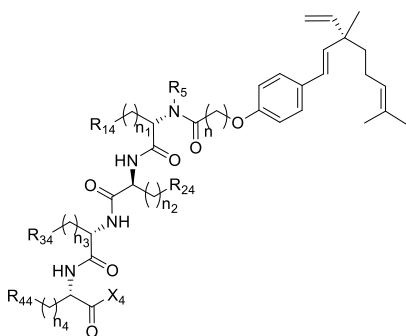
Further, the above bakuchiol derivative is selected from the following compounds:



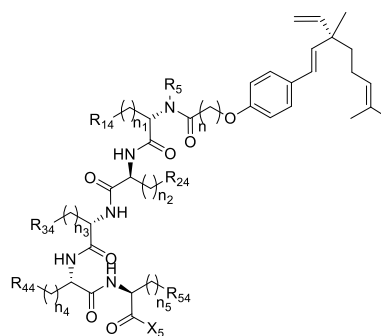
(III')



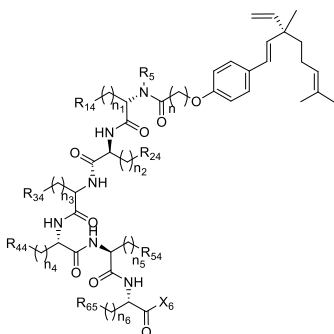
(IV')



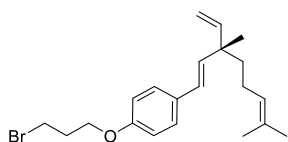
(V')



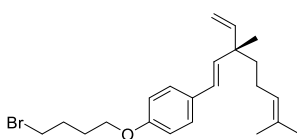
(VI')



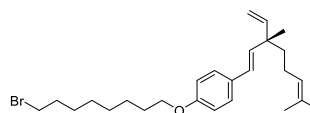
(VII').



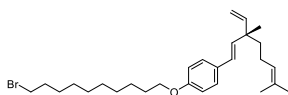
Compound 1



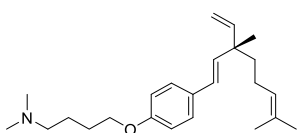
Compound 2



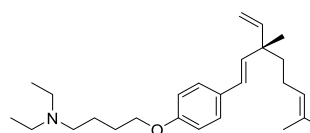
Compound 3



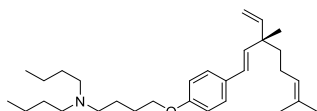
Compound 4



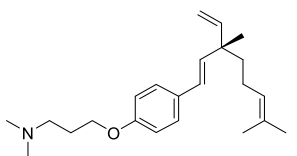
Compound 5



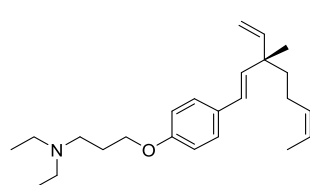
Compound 6



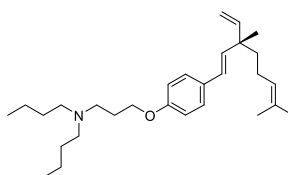
Compound 7



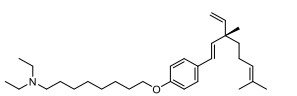
Compound 8



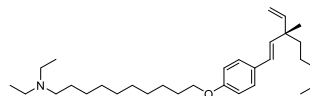
Compound 9



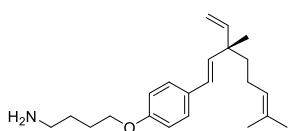
Compound 10



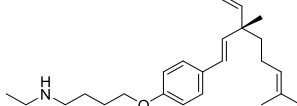
Compound 11



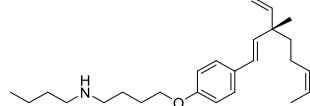
Compound 12



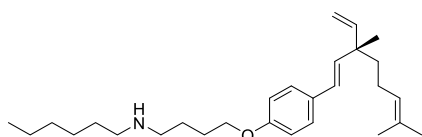
Compound 13



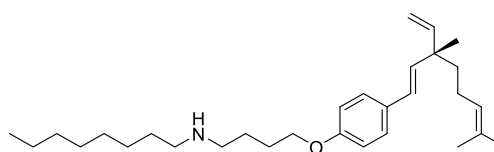
Compound 14



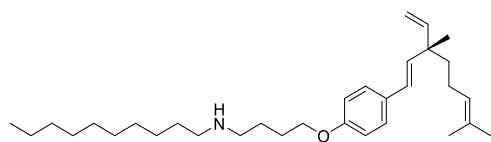
Compound 15



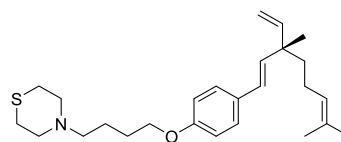
Compound 16



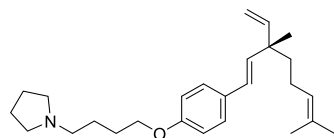
Compound 17



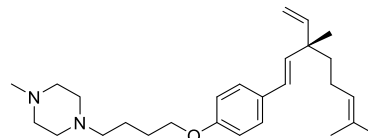
Compound 18



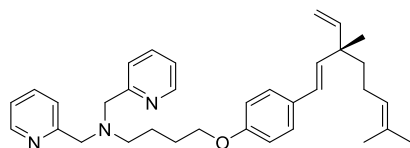
Compound 19



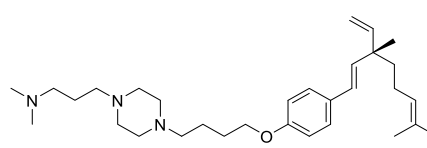
Compound 20



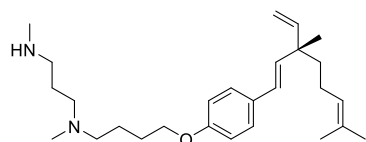
Compound 21



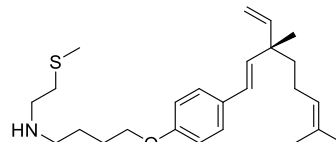
Compound 22



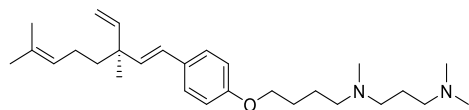
Compound 23



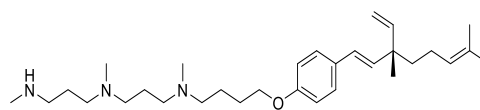
Compound 24



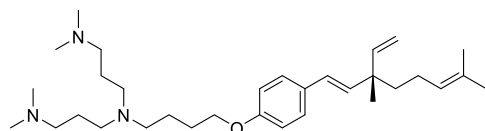
Compound 25



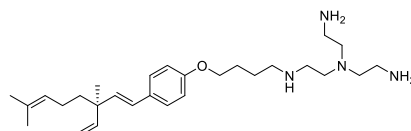
Compound 26



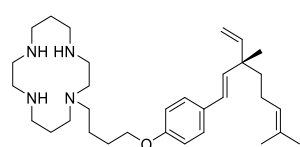
Compound 27



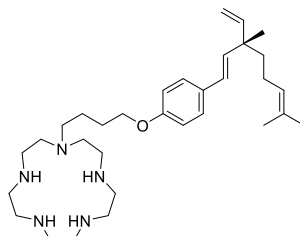
Compound 28



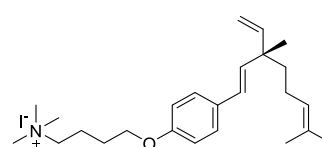
Compound 29



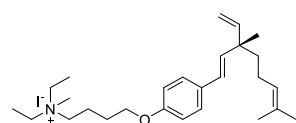
Compound 30



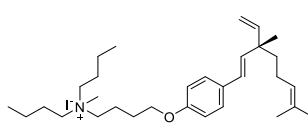
Compound 31



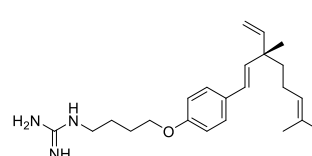
Compound 32



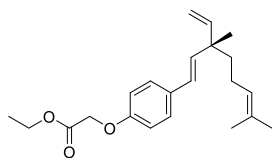
Compound 33



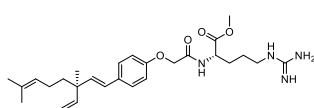
Compound 34



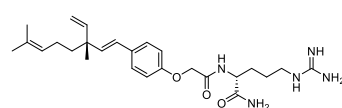
Compound 35



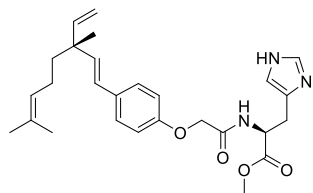
Compound 36



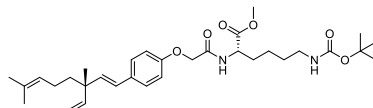
Compound 38



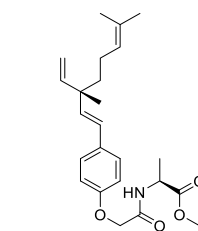
Compound 39



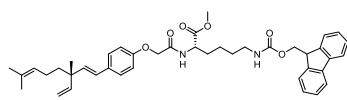
Compound 40



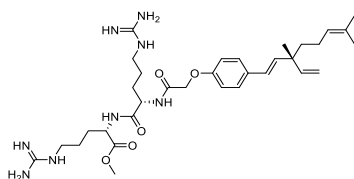
Compound 41



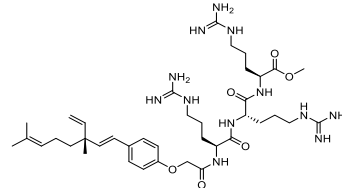
Compound 42



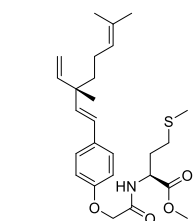
Compound 43



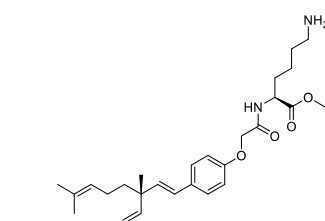
Compound 44



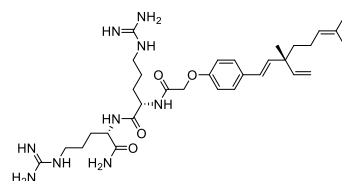
Compound 45



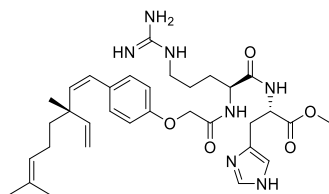
Compound 46



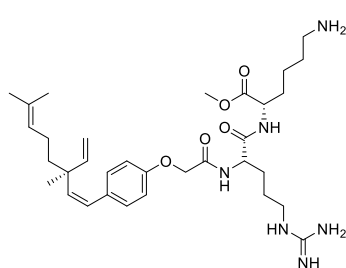
Compound 47



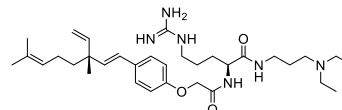
Compound 49



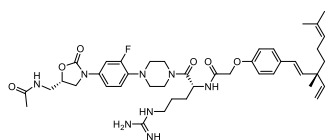
Compound 50



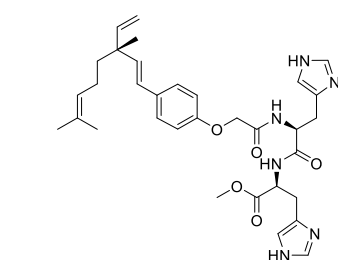
Compound 51



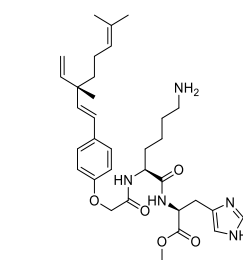
Compound 52



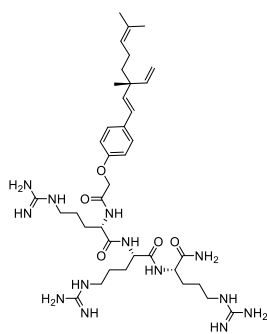
Compound 53



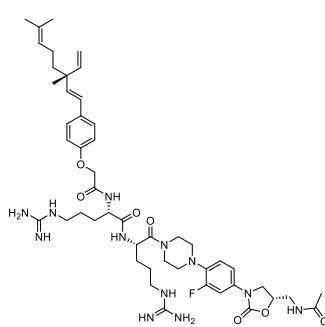
Compound 55



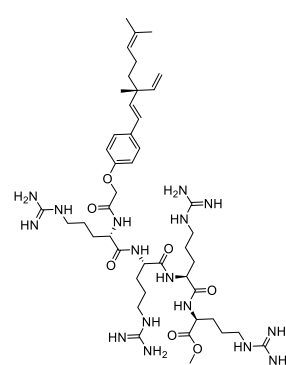
Compound 56



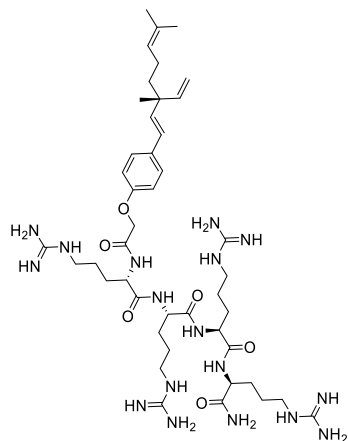
Compound 58



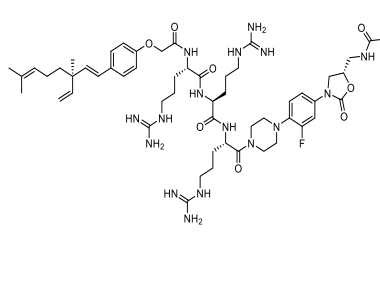
Compound 59



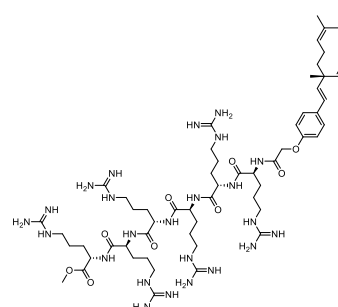
Compound 60



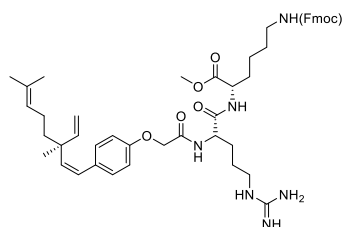
Compound 61



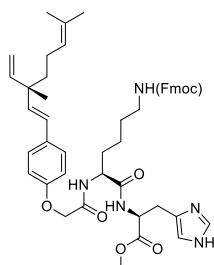
Compound 63



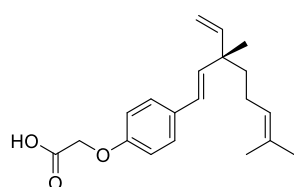
Compound 64



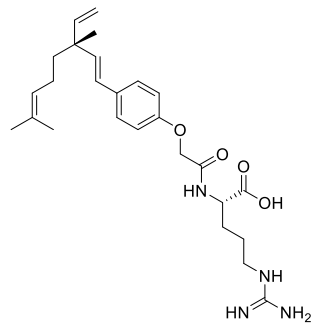
Compound 65



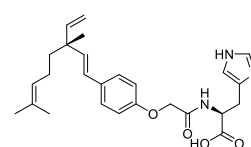
Compound 66



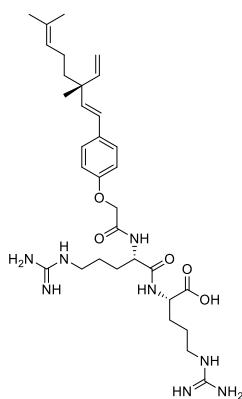
Compound 37



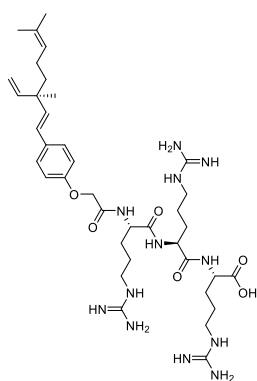
Compound 48



Compound 54



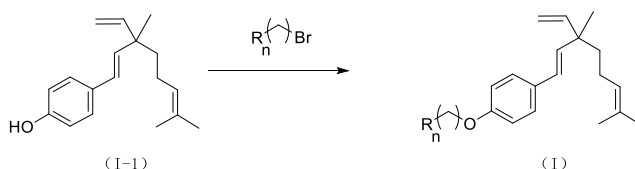
Compound 57



Compound 62

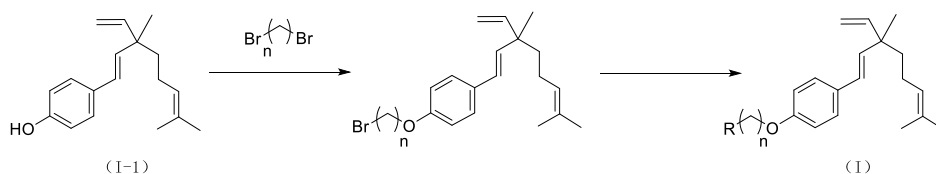
An embodiment of the disclosure also provides a preparation method of the above bakuchiol derivative.

(1) When R is a halogen, the preparation method includes the following step:



S101: a compound shown in formula (I-1) is reacted with R_nBr , to obtain a compound shown in formula (I) with R being a halogen;

(2) when R is NR_4R_5 , Y^- or $\text{H}_2\text{N}-\text{C}(\text{NH})=\text{NH}$, the preparation method includes the following steps:



S201: a compound shown in formula (I-1) is reacted with BrR_nBr , to obtain a compound shown in formula (I) with R being Br;

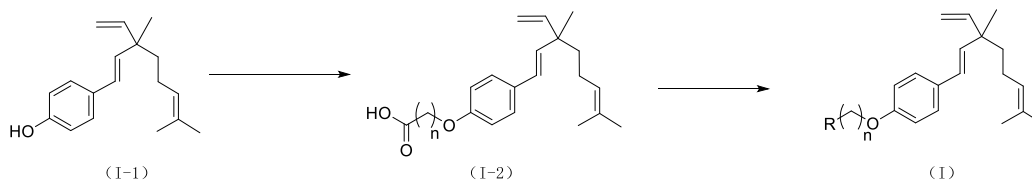
S202: the compound shown in formula (I) with R being Br is reacted with HNR_4R_5 , to obtain a compound shown in formula (I) with R being NR_4R_5 ;

S203: the compound shown in formula (I) with R being NR_4R_5 is reacted with haloalkyl, to obtain a compound shown in formula (I) with R being NR_4R_5 ; and

S204: a compound shown in formula (I) with R being NH_2 is reacted with $\text{HNNH}-\text{Cl}$, to

obtain a compound shown in formula (I) with R being $\text{H}_2\text{N}-\text{C}(\text{NH})=\text{N}-\text{H}$; and

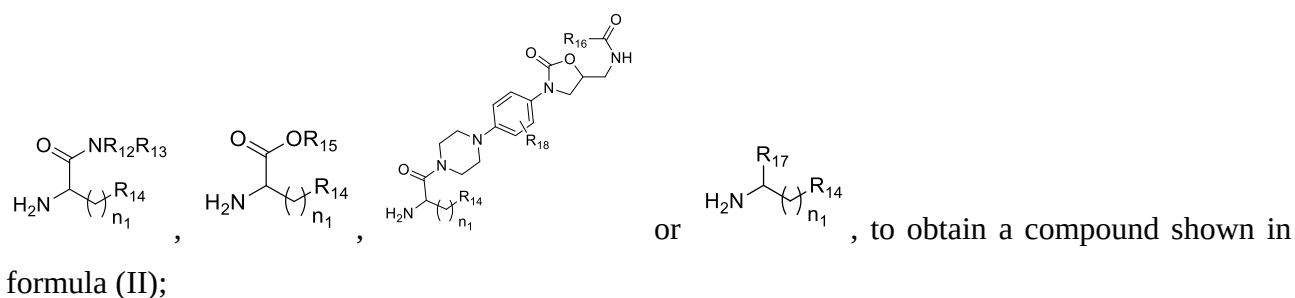
(3) when R is selected from CONR_1R_2 and $-\text{COOR}_3$, the preparation method includes the following steps:



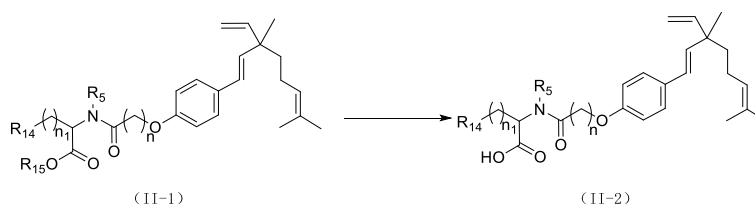
S301: a condensation reaction is performed on a compound shown in formula (I-1) and alkyl ester of bromoalkyl acid, to obtain a compound shown in formula (I) with R being $-\text{COOR}_3$;

further, alkyl ester of bromoalkyl acid is C_{1-6} alkyl bromoacetate;

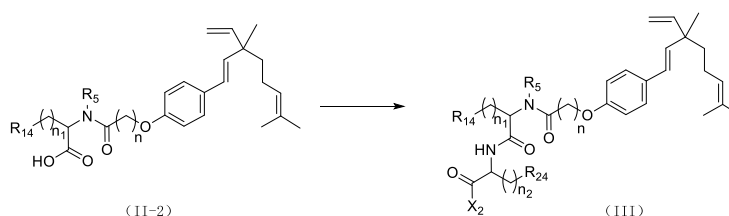
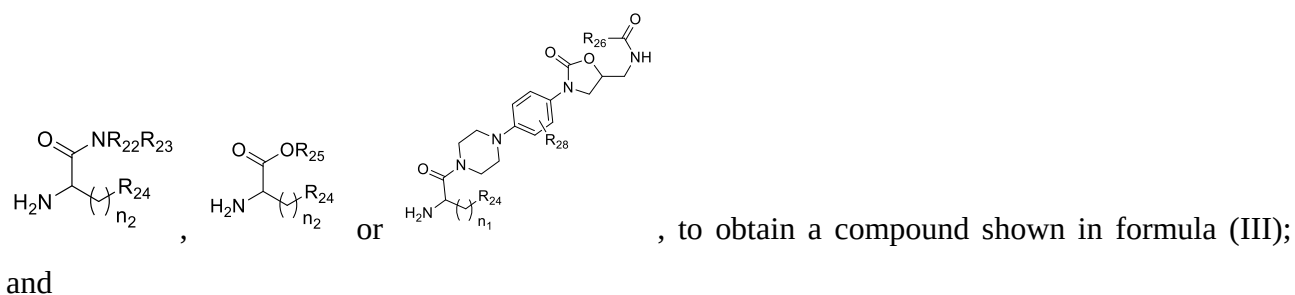
S302: a condensation reaction is performed on the compound shown in formula (I-2) and



S303: a hydrolysis reaction is performed on a compound shown in formula (II-1), to obtain a compound shown in formula (II-2);



S304: a condensation reaction is performed on the compound shown in formula (II-2) and



S305: optionally, according to this cycle, a compound containing an ester group is hydrolyzed, and a condensation reaction with corresponding amine is then performed to obtain compounds shown in formula (IV), (V), (VI) or (VII). The structure and definition of each general formula are as mentioned above, and will not be repeated here.

It could be understood that a step of ester hydrolysis is the same as S303, and a step of condensation reaction is the same as S304. The difference lies in that reaction substrates are different. For example, a compound shown in formula (III) with X_2 being OR_{35} is used as the substrate to perform a hydrolysis reaction to obtain carboxylic acid, and the carboxylic acid based compound is then used as the substrate to perform a condensation reaction with a corresponding substance. The conditions of the hydrolysis and condensation reactions are not particularly limited, and the existing hydrolysis and condensation reaction conditions may be adopted. These should be understood to be within the protection scope of the disclosure.

An embodiment of the disclosure also provides a pharmaceutical composition including the above bakuchiol derivative and a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable excipient.

An embodiment of the disclosure provides use of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition in preparation of antibacterial agents.

An embodiment of the disclosure provides use of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition in preparation of drugs for treating and preventing diseases caused by bacterial infection.

An embodiment of the disclosure provides a method for treating or preventing bacterial infection, including administration of an effective amount of the above bakuchiol derivative and a pharmaceutically acceptable salt thereof or the above pharmaceutical composition.

Specific examples are given below to illustrate the disclosure.

Preparation of compound 1

Bakuchiol (162 mg, 0.632 mmol) was dissolved in acetone (10 mL). Then, potassium carbonate (436.6 mg, 3.16 mmol) and 1,3-dibromopropane (480.8 μ L, 4.74 mmol) were added. The mixture was stirred under reflux for 6 hours. After the reaction, the reaction mixture was diluted with ethyl acetate and extracted twice with water. The organic phase was concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (petroleum ether/ethyl acetate, 8: 1, v/v), to afford compound **1** as a colorless clear oil (190.2 mg, 80%). ^1H NMR (400 MHz,

CDCl₃) δ 7.29 (d, J = 8.7 Hz, 2H), 6.84 (d, J = 8.7 Hz, 2H), 6.27 (d, J = 16.3 Hz, 1H), 6.07 (d, J = 16.2 Hz, 1H), 5.89 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.06–4.99 (m, 2H), 4.10 (t, J = 5.8 Hz, 2H), 3.60 (t, J = 6.5 Hz, 2H), 2.36–2.25 (m, 2H), 2.00–1.91 (m, 2H), 1.68 (s, 3H), 1.59 (s, 3H), 1.52–1.47 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 157.91, 146.05, 136.06, 131.38, 131.07, 127.27 (2 $\times$ CH), 126.57, 124.89, 114.64 (2 $\times$ CH), 111.96, 65.45, 42.62, 41.38, 32.48, 30.11, 25.79, 23.44, 23.32, 17.73. HRMS (ESI⁺): calculated for C₂₁H₂₉BrO [M + H]⁺ 377.1480, found 377.1475.

Preparation of compound 2

According to the method for synthesis of compound 1, bakuchiol (162 mg, 0.632 mmol), potassium carbonate (436.6 mg, 3.16 mmol) and 1,4-dibromobutane (565.3 μ L, 4.74 mmol) used as starting materials were prepared into compound 2 as a yellow oil (207.6 mg, 84%). ¹H NMR (400 MHz, CDCl₃) δ 7.28 (d, J = 8.7 Hz, 2H), 6.82 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.06 (d, J = 16.2 Hz, 1H), 5.88 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.06–4.98 (m, 2H), 3.99 (t, J = 6.1 Hz, 2H), 3.49 (t, J = 6.6 Hz, 2H), 2.11–2.03 (m, 2H), 1.99–1.91 (m, 4H), 1.68 (s, 3H), 1.58 (s, 3H), 1.52–1.47 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 158.09, 146.06, 135.94, 131.37, 130.87, 127.25 (2 $\times$ CH), 126.59, 124.90, 114.56 (2 $\times$ CH), 111.94, 66.94, 42.62, 41.38, 33.56, 29.55, 27.99, 25.78, 23.44, 23.31, 17.72. HRMS (ESI⁺): calculated for C₂₂H₃₁BrO [M + H]⁺ 391.1637 found 391.1632.

Preparation of compound 3

According to the method for synthesis of compound 1, bakuchiol (48.2 mg, 0.301 mmol), potassium carbonate (129.9 mg, 0.94 mmol) and 1,8-dibromooctane (259 μ L, 1.41 mmol) used as starting materials were prepared into compound 3 as a white oil (40.5 mg, 48%). ¹H NMR (400 MHz, CDCl₃) δ 7.28 (d, J = 8.8 Hz, 2H), 6.83 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.06 (d, J = 16.2 Hz, 1H), 5.89 (dd, J = 17.4, 10.8 Hz, 1H), 5.11 (t, J = 7.1 Hz, 1H), 5.06–4.98 (m, 2H), 3.95 (t, J = 6.5 Hz, 2H), 3.41 (t, J = 6.8 Hz, 2H), 2.00–1.91 (m, 2H), 1.90–1.73 (m, 4H), 1.68 (s, 3H), 1.59 (s, 3H), 1.52–1.42 (m, 6H), 1.38–1.34 (m, 4H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 158.34, 146.10, 135.73, 131.39, 130.59, 127.21 (2 $\times$ CH), 126.65, 124.90, 114.58 (2 $\times$ CH), 111.93, 68.02, 42.62, 41.39, 34.13, 32.87, 29.32, 29.28, 28.78, 28.19, 26.04, 25.81, 23.44, 23.32, 17.74. HRMS (ESI⁺): calculated for C₂₆H₃₉BrO [M + H]⁺ 447.2263, found 447.2258.

Preparation of compound 4

According to the method for synthesis of compound 1, bakuchiol (49.5 mg, 0.193 mmol), potassium carbonate (133.4 mg, 0.965 mmol) and 1,10-dibromodecane (325 μ L, 1.45 mmol) used

as starting materials were prepared into compound **4** as a yellow oil (46.9 mg, 52%). ¹H NMR (400 MHz, CDCl₃) δ 7.27 (d, *J* = 8.6 Hz, 2H), 6.82 (d, *J* = 8.8 Hz, 2H), 6.25 (d, *J* = 16.3 Hz, 1H), 6.05 (d, *J* = 16.2 Hz, 1H), 5.87 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.13–5.07 (m, 1H), 5.04–4.97 (m, 2H), 3.93 (t, *J* = 6.6 Hz, 2H), 3.40 (t, *J* = 6.9 Hz, 2H), 1.99–1.89 (m, 2H), 1.89–1.70 (m, 4H), 1.67 (s, 3H), 1.57 (s, 3H), 1.52–1.39 (m, 6H), 1.37–1.29 (m, 8H), 1.19 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 158.37, 146.10, 135.71, 131.39, 130.56, 127.21 (2×CH), 126.66, 124.91, 114.58 (2×CH), 111.93, 68.08, 42.62, 41.39, 34.18, 32.91, 29.54, 29.45, 29.43, 29.35, 28.84, 28.25, 26.11, 25.81, 23.44, 23.32, 17.75. HRMS (ESI⁺): calculated for C₂₈H₄₃BrO [M + H]⁺ 475.2576, found 475.3253.

Preparation of compound **5**

Compound **2** (35 mg, 0.089 mmol) was dissolved in an anhydrous DMF (4 mL) solution. Then, dimethylamine (1 mL) was added. The mixture was stirred at 50 °C for 24 hours. After the reaction, the reaction mixture was diluted with ethyl acetate and extracted twice with water. The organic phase was concentrated under reduced pressure. The crude product was purified by RP-HPLC, to afford compound **5** as a yellow oil (23 mg, 74%). ¹H NMR (400 MHz, CDCl₃) δ 7.27 (d, *J* = 9.9 Hz, 2H), 6.82 (d, *J* = 8.7 Hz, 2H), 6.26 (d, *J* = 16.3 Hz, 1H), 6.05 (d, *J* = 16.2 Hz, 1H), 5.88 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.14–5.07 (m, 1H), 5.05–4.98 (m, 2H), 3.97 (t, *J* = 6.4 Hz, 2H), 2.36–2.30 (m, 2H), 2.23 (s, 6H), 1.99–1.92 (m, 2H), 1.85–1.76 (m, 4H), 1.67 (s, 3H), 1.58 (s, 3H), 1.52–1.47 (m, 2H), 1.19 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 158.30, 146.10, 135.76, 131.36, 130.65, 127.20 (2×CH), 126.65, 124.91, 114.61, 111.91, 100.00, 67.83, 59.47, 45.50 (2×CH₃), 42.60, 41.39, 27.25, 25.78, 24.29, 23.45, 23.31, 17.72. HRMS (ESI⁺): calculated for C₂₄H₃₇NO [M + H]⁺ 356.2953, found 356.2947.

Preparation of compound **6**

According to the method for synthesis of compound **5**, compound **2** (35 mg, 0.089 mmol) and diethylamine (1 mL) used as starting materials were prepared into compound **6** as a yellow oil (22.3 mg, 66%). ¹H NMR (400 MHz, CDCl₃) δ 7.27 (d, *J* = 9.9 Hz, 2H), 6.82 (d, *J* = 8.7 Hz, 2H), 6.26 (d, *J* = 16.3 Hz, 1H), 6.05 (d, *J* = 16.2 Hz, 1H), 5.88 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.14–5.08 (m, 1H), 5.05–4.97 (m, 2H), 3.97 (t, *J* = 6.4 Hz, 2H), 2.61–2.46 (m, 6H), 2.00–1.92 (m, 2H), 1.82–1.74 (m, 4H), 1.67 (s, 3H), 1.58 (s, 3H), 1.52–1.46 (m, 2H), 1.19 (s, 3H), 1.03 (t, *J* = 7.2 Hz, 6H). ¹³C NMR (100 MHz, CDCl₃) δ 158.27, 146.09, 135.79, 131.36, 130.68, 127.21 (2×CH), 126.64, 124.90, 114.60 (2×CH), 111.91, 67.85, 52.48, 46.85 (2×CH₂), 42.60, 41.39, 27.40, 25.78 (2×CH₂), 23.45, 23.31, 17.72, 11.46 (2×CH₃). HRMS (ESI⁺): calculated for C₂₆H₄₁NO [M + H]⁺ 384.3266, found 384.3260.

Preparation of compound **7**

According to the method for synthesis of compound **9**, compound **2** (62.1 mg, 0.159 mmol) and dibutylamine (1 mL) used as starting materials were prepared into compound **7** as a yellow oil (59.1 mg, 88%). ^1H NMR (400 MHz, CDCl_3) δ 7.28 (d, J = 8.7 Hz, 2H), 6.83 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.05 (d, J = 16.2 Hz, 1H), 5.88 (dd, J = 17.4, 10.8 Hz, 1H), 5.14–5.07 (m, 1H), 5.06–4.97 (m, 2H), 3.96 (t, J = 6.5 Hz, 2H), 2.51–2.44 (m, 2H), 2.43–2.37 (m, 4H), 1.99–1.91 (m, 2H), 1.83–1.69 (m, 4H), 1.67 (s, 3H), 1.58 (s, 3H), 1.52–1.46 (m, 2H), 1.45–1.37 (m, 4H), 1.35–1.28 (m, 4H), 1.19 (s, 3H), 0.91 (t, J = 7.3 Hz, 6H). ^{13}C NMR (100 MHz,) δ 158.31, 146.10, 135.76, 131.36, 130.64, 127.20 (2 $\times$ CH), 126.66, 124.91, 114.61 (2 $\times$ CH), 111.91, 67.93, 53.81 (2 $\times$ CH₂), 53.76, 42.60, 41.39, 29.79, 29.03, 27.36, 25.78 (2 $\times$ CH₂), 23.45, 23.31, 20.82 (2 $\times$ CH₂), 17.72, 14.16 (2 $\times$ CH₃). HRMS (ESI⁺): calculated for C₃₀H₄₉NO [M + H]⁺ 440.3892, found 440.3892.

Preparation of compound **8**

According to the method for synthesis of compound **5**, compound **1** (49 mg, 0.130 mmol) and diethylamine (1 mL) used as starting materials were prepared into compound **8**. The crude product was purified by silica gel column chromatography (ethyl acetate/ethanol, 1: 1, v/v) as a yellow oil (38.6 mg, 87%). ^1H NMR (400 MHz, CDCl_3) δ 7.25 (d, J = 8.7 Hz, 2H), 6.81 (d, J = 8.6 Hz, 2H), 6.23 (d, J = 16.2 Hz, 1H), 6.03 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.4, 10.8 Hz, 1H), 5.08 (t, J = 6.6 Hz, 1H), 5.05–4.95 (m, 2H), 3.98 (t, J = 6.4 Hz, 2H), 2.47–2.41 (m, 2H), 2.24 (s, 6H), 1.98–1.89 (m, 4H), 1.65 (s, 3H), 1.56 (s, 3H), 1.50–1.43 (m, 2H), 1.17 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 158.24, 146.09, 135.80, 131.36, 130.71, 127.21 (2 $\times$ CH), 126.64, 124.91, 114.60 (2 $\times$ CH), 111.91, 66.32, 56.49, 45.53 (2 $\times$ CH₃), 42.60, 41.39, 27.57, 25.78, 23.44, 23.31, 17.72. HRMS (ESI⁺): calculated for C₂₃H₃₅NO [M + H]⁺ 342.2797, found 342.2791.

Preparation of compound **9**

According to the method for synthesis of compound **5**, compound **1** (59.6 mg, 0.158 mmol) and diethylamine (1 mL) used as starting materials were prepared into compound **9** as a yellow oil (48.9 mg, 91%). ^1H NMR (400 MHz, CDCl_3) δ 7.28 (d, J = 8.7 Hz, 2H), 6.83 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.06 (d, J = 16.2 Hz, 1H), 5.88 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.06–4.97 (m, 2H), 4.00 (t, J = 6.3 Hz, 2H), 2.64–2.51 (m, 6H), 2.00–1.88 (m, 4H), 1.67 (s, 3H), 1.58 (s, 3H), 1.52–1.46 (m, 2H), 1.20 (s, 3H), 1.04 (t, J = 7.1 Hz, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 158.33, 146.10, 135.74, 131.35, 130.63, 127.19 (2 $\times$ CH), 126.67, 124.91, 114.61 (2 $\times$ CH), 111.91, 66.49, 49.46, 47.09 (2 $\times$ CH₂), 42.60, 41.39, 27.06, 25.78, 23.45, 23.32, 17.72, 11.84 (2 $\times$ CH₃). HRMS (ESI⁺): calculated for C₂₅H₃₉NO [M + H]⁺ 370.3110, found 370.3103.

Preparation of compound **10**

According to the method for synthesis of compound **5**, compound **1** (59.5 mg, 0.158 mmol) and dibutylamine (1 mL) used as starting materials were prepared into compound **10** as a colorless clear oil (56 mg, 86%). ^1H NMR (400 MHz, CDCl_3) δ 7.28 (d, J = 8.7 Hz, 2H), 6.83 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.06 (d, J = 16.2 Hz, 1H), 5.89 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.06–4.98 (m, 2H), 4.00 (t, J = 6.4 Hz, 2H), 2.61–2.54 (m, 2H), 2.44–2.38 (m, 4H), 1.97–1.87 (m, 4H), 1.68 (s, 3H), 1.59 (s, 3H), 1.52–1.46 (m, 2H), 1.44–1.38 (m, 4H), 1.33–1.28 (m, 4H), 1.20 (s, 3H), 0.90 (t, J = 7.3 Hz, 6H). ^{13}C NMR (100 MHz, CDCl_3) δ 158.36, 146.11, 135.70, 131.35, 130.59, 127.18 (2 $\times$ CH), 126.69, 124.92, 114.61 (2 $\times$ CH), 111.90, 66.45, 54.06 (2 $\times$ CH₂), 50.63, 42.60, 41.40, 29.38, 27.17, 25.78 (2 $\times$ CH₂), 23.46, 23.32, 20.81 (2 $\times$ CH₂), 17.72, 14.18 (2 $\times$ CH₃). HRMS (ESI⁺): calculated for $\text{C}_{29}\text{H}_{47}\text{NO}$ [$\text{M} + \text{H}$]⁺ 426.3736, found 426.3728.

Preparation of compound **11**

According to the method for synthesis of compound **5**, compound **3** (40.5 mg, 0.091 mmol) and diethylamine (1 mL) used as starting materials were prepared into compound **11** as a yellow oil (32.3 mg, 81%). ^1H NMR (400 MHz, CD_3OD) δ 7.27 (d, J = 8.7 Hz, 2H), 6.82 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.07 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.05–4.98 (m, 2H), 3.95 (t, J = 6.4 Hz, 2H), 2.89 (q, J = 7.3 Hz, 4H), 2.81–2.75 (m, 2H), 2.00–1.92 (m, 2H), 1.81–1.72 (m, 2H), 1.66 (s, 3H), 1.62–1.55 (m, 5H), 1.51–1.45 (m, 4H), 1.42–1.34 (m, 6H), 1.20–1.15 (m, 9H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.78, 147.33, 136.40, 131.99, 131.82, 128.15 (2 $\times$ CH), 128.01, 125.94, 115.50 (2 $\times$ CH), 112.28, 68.86, 53.35, 47.95 (2 $\times$ CH₂), 43.54, 42.57, 30.36 (2 $\times$ CH₂), 30.30, 28.09, 27.07, 25.90 (2 $\times$ CH₂), 24.36, 23.86, 17.69, 10.06 (2 $\times$ CH₃). HRMS (ESI⁺): calculated for $\text{C}_{30}\text{H}_{49}\text{NO}$ [$\text{M} + \text{H}$]⁺ 440.3892, found 440.3875.

Preparation of compound **12**

According to the method for synthesis of compound **5**, compound **4** (46.9 mg, 0.099 mmol) and diethylamine (1 mL) used as starting materials were prepared into compound **12** as an orange oil (34.8 mg, 76%). ^1H NMR (400 MHz, CD_3OD) δ 7.26 (d, J = 8.7 Hz, 2H), 6.82 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.07 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.06–4.97 (m, 2H), 3.94 (t, J = 6.4 Hz, 2H), 3.18 (q, J = 7.3 Hz, 4H), 3.11–3.02 (m, 2H), 2.02–1.91 (m, 2H), 1.82–1.60 (m, 7H), 1.57 (s, 3H), 1.52–1.42 (m, 4H), 1.42–1.33 (m, 10H), 1.29 (t, J = 7.3 Hz, 6H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.78, 147.31, 136.39, 131.98, 131.79, 128.15 (2 $\times$ CH), 128.00, 125.94, 115.49 (2 $\times$ CH), 112.29, 68.91, 52.95, 48.15 (2 $\times$ CH₂), 43.54, 42.56, 30.55, 30.44 (2 $\times$ CH₂), 30.41, 30.20, 27.64, 27.15, 25.92, 24.91, 24.35, 23.85, 17.70, 9.08 (2 $\times$ CH₃).

HRMS (ESI⁺): calculated for C₃₂H₅₃NO [M + H]⁺ 468.4205, found 468.4199.

Preparation of compound **13**

According to the method for synthesis of compound **24**, compound **2** (69.3 mg, 0.177 mmol) and ammonia water (3 mL) used as starting materials were prepared into compound **13** as a yellow foam (44.8 mg, 77%). ¹H NMR (400 MHz, CD₃OD) δ 7.28 (d, *J* = 8.7 Hz, 2H), 6.88–6.83 (m, 2H), 6.26 (d, *J* = 16.3 Hz, 1H), 6.08 (d, *J* = 16.3 Hz, 1H), 5.90 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.14–5.09 (m, 1H), 5.05–4.99 (m, 2H), 4.03 (t, *J* = 5.3 Hz, 2H), 3.13–3.06 (m, 2H), 2.00–1.84 (m, 6H), 1.66 (s, 3H), 1.57 (s, 3H), 1.50–1.45 (m, 2H), 1.19 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 159.44, 147.28, 136.63, 132.14, 131.98, 128.18 (2×CH), 127.92, 125.93, 115.51 (2×CH), 112.29, 68.17, 43.54, 42.54, 40.52, 27.29, 25.89, 25.69, 24.35, 23.86, 17.68. HRMS (ESI⁺): calculated for C₂₂H₃₃NO [M + H]⁺ 328.2640, found 328.2632.

Preparation of compound **14**

According to the method for synthesis of compound **5**, compound **2** (38.9 mg, 0.099 mmol) and ethylamine (1 mL) used as starting materials were prepared into compound **14** as a yellow oil (30.1 mg, 85%). ¹H NMR (400 MHz, CD₃OD) δ 7.28 (d, *J* = 8.7 Hz, 2H), 6.85 (d, *J* = 8.7 Hz, 2H), 6.26 (d, *J* = 16.3 Hz, 1H), 6.08 (d, *J* = 16.3 Hz, 1H), 5.90 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.12 (t, *J* = 7.2 Hz, 1H), 5.05–4.97 (m, 2H), 4.02 (t, *J* = 5.3 Hz, 2H), 3.11–2.98 (m, 4H), 2.00–1.92 (m, 2H), 1.91–1.81 (m, 4H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.44 (m, 2H), 1.31 (t, *J* = 7.3 Hz, 3H), 1.19 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 159.44, 147.31, 136.69, 132.20, 132.00, 128.21 (2×CH), 127.93, 125.95, 115.54 (2×CH), 112.31, 68.12, 48.22, 43.94, 43.56, 42.56, 27.38, 25.90, 24.44, 24.36, 23.87, 17.69, 11.56. HRMS (ESI⁺): calculated for C₂₄H₃₇NO [M + H]⁺ 356.2953, found 356.2949.

Preparation of compound **15**

According to the method for synthesis of compound **5**, compound **2** (43 mg, 0.11 mmol) and n-butylamine (1 mL) used as starting materials were prepared into compound **15** as a yellow oil (35.5 mg, 84%). ¹H NMR (400 MHz, CD₃OD) δ 7.28 (d, *J* = 7.3 Hz, 2H), 6.85 (d, *J* = 8.4 Hz, 2H), 6.26 (d, *J* = 15.8 Hz, 1H), 6.12–6.03 (m, 1H), 5.96–5.84 (m, 1H), 5.11 (t, *J* = 7.8 Hz, 1H), 5.05–4.98 (m, 2H), 4.06–3.99 (m, 2H), 3.08–3.00 (m, 2H), 3.00–2.93 (m, 2H), 2.00–1.91 (m, 2H), 1.90–1.80 (m, 4H), 1.70–1.61 (m, 5H), 1.57 (s, 3H), 1.50–1.37 (m, 4H), 1.20–1.17 (m, 3H), 1.01–0.95 (m, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 159.41, 147.28, 136.67, 132.16, 132.00, 128.19 (2×CH), 127.90, 125.92, 115.54 (2×CH), 112.30, 68.14, 48.74 (2×CH₂), 43.53, 42.53, 29.44, 27.41, 25.89, 24.48, 24.33, 23.85, 20.84, 17.68, 13.92. HRMS (ESI⁺): calculated for C₂₆H₄₁NO [M + H]⁺ 384.3266, found 384.3261.

Preparation of compound **16**

According to the method for synthesis of compound **5**, compound **2** (65.8 mg, 0.168 mmol) and n-hexylamine (1 mL) used as starting materials were prepared into compound **16** as a yellow oil (46.7 mg, 68%). ^1H NMR (400 MHz, CDCl_3) δ 7.24 (d, J = 8.1 Hz, 2H), 6.76 (d, J = 8.7 Hz, 2H), 6.23 (d, J = 16.3 Hz, 1H), 6.03 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.4, 10.8 Hz, 1H), 5.13–5.06 (m, 1H), 5.04–4.96 (m, 2H), 3.89 (t, J = 5.9 Hz, 2H), 2.98–2.80 (m, 4H), 1.98–1.86 (m, 4H), 1.82–1.65 (m, 7H), 1.56 (s, 3H), 1.50–1.44 (m, 2H), 1.31–1.21 (m, 6H), 1.17 (s, 3H), 0.84 (t, J = 6.8 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 168.26, 157.88, 146.03, 135.96, 131.36, 130.96, 127.25, 126.56, 124.88, 114.54 (2 $\times$ CH), 111.95, 67.04, 47.65, 47.28, 42.60, 41.37, 31.28, 26.58, 26.51, 25.99, 25.78, 23.41, 23.30, 23.10, 22.50, 17.71, 14.00. HRMS (ESI $^+$): calculated for $\text{C}_{28}\text{H}_{45}\text{NO}$ $[\text{M} + \text{H}]^+$ 412.3579, found 412.3573.

Preparation of compound **17**

According to the method for synthesis of compound **5**, compound **2** (34.7 mg, 0.089 mmol) and n-octylamine (1 mL) used as starting materials were prepared into compound **17** as a yellow oil (28.4 mg, 72%). ^1H NMR (400 MHz, CD_3OD) δ 7.25 (d, J = 8.8 Hz, 2H), 6.82 (d, J = 8.8 Hz, 2H), 6.24 (d, J = 16.3 Hz, 1H), 6.05 (d, J = 16.3 Hz, 1H), 5.88 (dd, J = 17.4, 10.8 Hz, 1H), 5.12–5.06 (m, 1H), 5.04–4.95 (m, 2H), 4.07–3.92 (m, 2H), 3.08–2.76 (m, 4H), 1.99–1.78 (m, 6H), 1.63 (s, 5H), 1.55 (s, 3H), 1.48–1.42 (m, 2H), 1.36–1.26 (m, 10H), 1.17 (s, 3H), 0.88 (t, J = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.44, 147.30, 136.67, 132.18, 131.99, 128.20, 127.93, 125.94, 115.54 (2 $\times$ CH), 112.29, 101.33, 68.17, 48.55, 48.54, 43.55, 42.55, 32.90, 30.24, 30.20, 30.19, 27.68, 27.45, 25.88, 24.35, 23.87, 23.68, 23.67, 17.67, 14.41. HRMS (ESI $^+$): calculated for $\text{C}_{30}\text{H}_{49}\text{NO}$ $[\text{M} + \text{H}]^+$ 440.3892, found 440.3886.

Preparation of compound **18**

According to the method for synthesis of compound **5**, compound **2** (66.7 mg, 0.170 mmol) and n-decylamine (1 mL) used as starting materials were prepared into compound **18** as a yellow oil (64.8 mg, 81%). ^1H NMR (400 MHz, CDCl_3) δ 7.26–7.23 (m, 2H), 6.77 (d, J = 8.8 Hz, 2H), 6.24 (d, J = 16.2 Hz, 1H), 6.04 (d, J = 16.2 Hz, 1H), 5.87 (dd, J = 17.4, 10.7 Hz, 1H), 5.13–5.07 (m, 1H), 5.04–4.97 (m, 2H), 3.90 (t, J = 5.9 Hz, 2H), 2.99–2.90 (m, 2H), 2.89–2.81 (m, 2H), 1.99–1.85 (m, 4H), 1.84–1.60 (m, 7H), 1.57 (s, 3H), 1.51–1.45 (m, 2H), 1.29–1.18 (m, 17H), 0.86 (t, J = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 167.98, 157.87, 146.01, 135.97, 131.35, 130.96, 127.25, 126.56, 124.88, 114.54 (2 $\times$ CH), 111.95, 67.04, 47.68, 47.32, 42.60, 41.36, 31.95, 29.56, 29.52, 29.35, 29.18, 26.87, 26.57, 26.05, 25.78, 23.41, 23.30, 23.11, 22.74, 17.71, 14.19. HRMS (ESI $^+$):

calculated for $C_{32}H_{53}NO$ $[M + H]^+$ 468.4205, found 468.4197.

Preparation of compound **19**

According to the method for synthesis of compound **8**, compound **2** (47.3 mg, 0.121 mmol) and thiomorpholine (1 mL) used as starting materials were prepared into compound **19** as a yellow oil (39.5 mg, 81%). 1H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, J = 8.7 Hz, 2H), 6.82 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.06 (d, J = 16.2 Hz, 1H), 5.88 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.07 (m, 1H), 5.06–4.96 (m, 2H), 3.96 (t, J = 6.3 Hz, 2H), 2.75–2.61 (m, 8H), 2.46–2.38 (m, 2H), 2.00–1.91 (m, 2H), 1.81–1.73 (m, 2H), 1.70–1.62 (m, 5H), 1.58 (s, 3H), 1.52–1.45 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.24, 146.08, 135.82, 131.36, 130.70, 127.22 (2 $\times$ CH), 126.63, 124.90, 114.58 (2 $\times$ CH), 111.93, 67.77, 58.99, 55.08 (2 $\times$ CH₂), 42.61, 41.39, 28.07 (2 $\times$ CH₂), 27.31, 25.79, 23.45, 23.32, 23.13, 17.73. HRMS (ESI⁺): calculated for $C_{26}H_{39}NOS$ $[M + H]^+$ 414.2831, found 414.2822.

Preparation of compound **20**

According to the method for synthesis of compound **5**, compound **2** (47.3 mg, 0.121 mmol) and tetrahydropyrrole (1 mL) used as starting materials were prepared into compound **20** as a colorless clear oil (40.5 mg, 88%). 1H NMR (400 MHz, $CDCl_3$) δ 7.27 (d, J = 8.7 Hz, 2H), 6.84 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.07 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.07 (m, 1H), 5.05–4.97 (m, 2H), 4.00 (t, J = 5.6 Hz, 2H), 2.88 (dt, J = 15.1, 6.7 Hz, 6H), 1.99–1.88 (m, 6H), 1.83–1.76 (m, 4H), 1.66 (s, 3H), 1.57 (s, 3H), 1.50–1.44 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.55, 147.30, 136.57, 132.04, 131.97, 128.18 (2 $\times$ CH), 127.96, 125.95, 115.55 (2 $\times$ CH), 112.30, 68.38, 56.69, 54.98 (2 $\times$ CH₂), 43.54, 42.55, 28.00, 25.90, 25.32, 24.35, 24.06 (2 $\times$ CH₂), 23.88, 17.70. HRMS (ESI⁺): calculated for $C_{26}H_{39}NO$ $[M + H]^+$ 382.3110, found 382.3101.

Preparation of compound **21**

According to the method for synthesis of compound **5**, compound **2** (66.3 mg, 0.169 mmol) and 1-methylpiperazine (1 mL) used as starting materials were prepared into compound **21** as a brown oil (48.7 mg, 71%). 1H NMR (400 MHz, $CDCl_3$) δ 7.28–7.25 (m, 2H), 6.79 (d, J = 8.7 Hz, 2H), 6.24 (d, J = 16.3 Hz, 1H), 6.04 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.4, 10.8 Hz, 1H), 5.12–5.05 (m, 1H), 5.03–4.96 (m, 2H), 3.94 (t, J = 6.1 Hz, 2H), 2.88–2.45 (m, 10H), 2.43 (s, 3H), 1.98–1.88 (m, 2H), 1.82–1.67 (m, 4H), 1.65 (s, 3H), 1.56 (s, 3H), 1.50–1.44 (m, 2H), 1.17 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.96, 158.13, 146.05, 135.88, 131.37, 130.76, 127.23, 126.58, 124.88, 114.55 (2 $\times$ CH), 111.94, 67.53, 57.50, 53.62 (2 $\times$ CH₂), 51.37 (2 $\times$ CH₂), 44.64, 42.61, 41.37, 27.14, 25.79,

23.42, 23.30, 22.91, 17.72. HRMS (ESI⁺): calculated for C₂₇H₄₂N₂O [M + H]⁺ 411.3375, found 411.3365.

Preparation of compound **22**

According to the method for synthesis of compound **5**, compound **2** (66.3 mg, 0.169 mmol) and dimethylpyridinamine (1 mL) used as starting materials were prepared into compound **22** as a brown gel (71.4 mg, 83%). ¹H NMR (400 MHz, CDCl₃) δ 8.53–8.48 (m, 2H), 7.65–7.58 (m, 2H), 7.51 (d, *J* = 7.8 Hz, 2H), 7.26–7.22 (m, 2H), 7.15–7.08 (m, 2H), 6.75 (d, *J* = 8.7 Hz, 2H), 6.24 (d, *J* = 16.3 Hz, 1H), 6.04 (d, *J* = 16.2 Hz, 1H), 5.87 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.13–5.06 (m, 1H), 5.04–4.96 (m, 2H), 3.85 (t, *J* = 6.2 Hz, 2H), 3.81 (s, 4H), 2.59 (t, *J* = 6.9 Hz, 2H), 1.99–1.89 (m, 2H), 1.80–1.62 (m, 7H), 1.56 (s, 3H), 1.51–1.44 (m, 2H), 1.18 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 159.94, 158.24 (2×C), 149.02 (2×CH), 146.08, 136.51 (2×CH), 135.75, 131.36, 130.61, 127.18 (2×CH), 126.65, 124.90, 123.01 (2×CH), 122.02 (2×CH), 114.58 (2×CH), 111.93, 67.74, 60.50 (2×CH₂), 53.96, 42.61, 41.38, 27.04, 25.79, 23.70, 23.44, 23.31, 17.73. HRMS ((ESI⁺): calculated for C₃₄H₄₃N₃O [M + H]⁺ 510.3484, found 510.3478.

Preparation of compound **23**

According to the method for synthesis of compound **5**, compound **2** (67.6 mg, 0.173 mmol) and 1-(3-dimethylaminopropyl) piperazine (1 mL) used as starting materials were prepared into compound **23** as a brown gel (68.4 mg, 83%). ¹H NMR (400 MHz, CDCl₃) δ 7.27–7.23 (m, 2H), 6.79 (d, *J* = 8.5 Hz, 2H), 6.23 (d, *J* = 16.2 Hz, 1H), 6.03 (d, *J* = 16.2 Hz, 1H), 5.85 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.11–5.05 (m, 1H), 5.03–4.94 (m, 2H), 3.93 (t, *J* = 6.1 Hz, 2H), 2.63–2.39 (m, 20H), 1.97–1.88 (m, 2H), 1.82–1.73 (m, 4H), 1.69–1.62 (m, 5H), 1.55 (s, 3H), 1.49–1.42 (m, 2H), 1.17 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 168.54, 158.19, 146.06, 135.80, 131.36, 130.68, 127.21, 126.61, 124.88, 114.56 (2×CH), 111.92, 67.67, 57.96, 56.62, 55.66, 52.62 (2×CH₂), 43.90 (2×CH₃), 42.60, 41.37, 27.28, 25.78, 23.43, 23.30, 23.16, 23.07, 17.72. HRMS (ESI⁺): calculated for C₃₁H₅₁N₃O [M + H]⁺ 482.4110, found 482.4101.

Preparation of compound **24**

According to the method for synthesis of compound **5**, compound **2** (63.6 mg, 0.163 mmol) and *N,N'*-dimethyl-1,3-propanediamine (203 μL, 1.62 mmol) used as starting materials were prepared into compound **24** as a yellow oil (56.5 mg, 87%). ¹H NMR (400 MHz, CD₃OD) δ 7.27 (dd, *J* = 8.7, 1.9 Hz, 2H), 6.84 (d, *J* = 8.8 Hz, 2H), 6.26 (d, *J* = 16.3 Hz, 1H), 6.07 (d, *J* = 16.3 Hz, 1H), 5.90 (dd, *J* = 17.4, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.98 (m, 2H), 4.03–3.95 (m, 2H), 3.37–3.31 (m, 2H), 2.98–2.84 (m, 2H), 2.60–2.36 (m, 5H), 2.33–2.24 (m, 3H), 2.00–1.92 (m, 2H), 1.85–1.67 (m,

6H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.45 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 157.84, 145.92, 136.05, 131.38, 130.90, 127.30 (2 $\times$ CH), 126.43, 124.83, 114.54 (2 $\times$ CH), 112.03, 67.10, 55.01, 47.70, 45.12, 43.16, 42.98, 42.60, 41.31, 26.45, 25.82 (2 $\times$ CH₂), 23.29, 23.17, 21.76, 17.75. HRMS ((ESI⁺): calculated for $\text{C}_{27}\text{H}_{44}\text{N}_2\text{O}$ $[\text{M} + \text{H}]^+$ 413.3532, found 413.3523.

Preparation of compound **25**

According to the method for synthesis of compound **24**, compound **2** (47 mg, 0.12 mmol) and 2-(methylthio)ethylamine (55.8 μL , 0.600 mmol) used as starting materials were prepared into compound **25** as a yellow oil (23.2 mg, 60%). ^1H NMR (400 MHz, CDCl_3) δ 7.27 (d, J = 8.8 Hz, 2H), 6.82 (d, J = 8.8 Hz, 2H), 6.25 (d, J = 16.3 Hz, 1H), 6.05 (d, J = 16.2 Hz, 1H), 5.88 (dd, J = 17.4, 10.8 Hz, 1H), 5.13–5.07 (m, 1H), 5.05–4.98 (m, 2H), 3.96 (t, J = 6.3 Hz, 2H), 2.85 (t, J = 6.5 Hz, 2H), 2.73–2.61 (m, 4H), 2.23 (s, 3H), 2.10–2.10 (m, 2H), 1.98–1.91 (m, 2H), 1.86–1.77 (m, 2H), 1.73–1.69 (m, 1H), 1.67 (s, 3H), 1.57 (s, 3H), 1.51–1.46 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 158.20, 146.07, 135.81, 131.38, 130.70, 127.22 (2 $\times$ CH), 126.62, 124.89, 114.58 (2 $\times$ CH), 111.93, 67.75, 49.10, 47.65, 42.61, 41.38, 34.12, 27.11, 26.51, 25.79, 23.43, 23.31, 17.73, 15.36. HRMS (ESI⁺): calculated for $\text{C}_{25}\text{H}_{39}\text{NOS}$ $[\text{M} + \text{H}]^+$ 402.2831, found 402.2822.

Preparation of compound **26**

According to the method for synthesis of compound **24**, compound **2** (60.65 mg, 0.155 mmol) and *N,N,N'*-trimethyl-1,3-propanediamine (113.5 μL , 0.775 mmol) used as starting materials were prepared into compound **26** as a yellow oil (46.3 mg, 70%). ^1H NMR (400 MHz, CD_3OD) δ 7.29 (d, J = 8.7 Hz, 2H), 6.86 (d, J = 8.8 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.08 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.4, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.98 (m, 2H), 4.03 (t, J = 5.5 Hz, 2H), 3.07–2.97 (m, 6H), 2.73–2.69 (m, 9H), 2.07–1.92 (m, 4H), 1.90–1.81 (m, 4H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.44 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.47, 147.29, 136.65, 132.13, 131.99, 128.20 (2 $\times$ CH), 127.92, 125.94, 115.55 (2 $\times$ CH), 112.30, 68.20, 57.45, 43.87, 43.81, 43.55 (3 $\times$ CH₃), 42.54, 40.78, 27.58, 25.89, 24.35, 23.84, 22.92, 21.62, 17.69. HRMS (ESI⁺): calculated for $\text{C}_{28}\text{H}_{46}\text{N}_2\text{O}$ $[\text{M} + \text{H}]^+$ 427.3688, found 427.3679.

Preparation of compound **27**

According to the method for synthesis of compound **5**, compound **2** (67.1 mg, 0.171 mmol) and *N,N',N''*-trimethyldipropylenetriamine (208 μL , 1.03 mmol) used as starting materials were prepared into compound **27** as a yellow oil (58.3 mg, 72%). ^1H NMR (400 MHz, CD_3OD) δ 7.28 (d, J = 8.7 Hz, 2H), 6.85 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.08 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.4, 10.8 Hz, 1H), 5.16–5.09 (m, 1H), 5.06–4.98 (m, 2H), 4.01 (t, J = 5.2 Hz, 2H), 3.38–

3.31 (m, 2H), 2.99–2.84 (m, 2H), 2.82–2.61 (m, 5H), 2.56–2.36 (m, 7H), 2.34–2.23 (m, 3H), 2.00–1.90 (m, 2H), 1.85–1.72 (m, 8H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.45 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 157.79, 145.96, 136.06, 131.41, 130.97, 127.29 (2 $\times$ CH), 126.44, 124.82, 114.48 (2 $\times$ CH), 112.00, 66.92, 55.61, 54.00, 53.58, 53.38, 47.60, 42.61 (2 $\times$ CH₃), 41.32, 40.89, 39.50, 33.14, 26.52, 25.81, 23.32, 23.28, 22.09, 20.99, 17.73. HRMS (ESI⁺): calculated for $\text{C}_{31}\text{H}_{53}\text{N}_3\text{O}$ [M + H]⁺ 484.4267, found 484.4258.

Preparation of compound **28**

According to the method for synthesis of compound **24**, compound **2** (56 mg, 0.143 mmol) and *N*'-[3-(dimethylamino)propyl]-*N,N*-dimethyl-1,3-propanediamine (159 μL , 0.715 mmol) used as starting materials were prepared into compound **28** as a yellow gel (67.1 mg, 94%). ^1H NMR (400 MHz, CD_3OD) δ 7.32–7.27 (m, 2H), 6.91–6.83 (m, 2H), 6.27 (d, J = 16.2 Hz, 1H), 6.14–6.05 (m, 1H), 5.90 (dd, J = 17.5, 10.8 Hz, 1H), 5.16–5.08 (m, 1H), 5.06–4.98 (m, 2H), 4.12–3.98 (m, 2H), 3.50–3.38 (m, 3H), 3.21–2.97 (m, 9H), 2.87–2.72 (m, 10H), 2.24–1.73 (m, 10H), 1.66 (s, 3H), 1.57 (s, 3H), 1.50–1.45 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.57, 159.37, 147.28, 136.63, 131.99, 128.21, 127.90, 127.88, 125.92, 115.56, 115.54, 112.30, 68.53, 67.96, 51.59, 51.37, 51.32, 43.55 (2 $\times$ CH₃), 43.41, 43.40, 43.35 (2 $\times$ CH₃), 42.53, 27.13, 25.89, 25.87, 24.34, 23.83, 20.73, 17.68, 17.66. HRMS (ESI⁺): calculated for $\text{C}_{32}\text{H}_{55}\text{N}_3\text{O}$ [M + H]⁺ 498.4423, found 498.4411.

Preparation of compound **29**

According to the method for synthesis of compound **24**, compound **2** (50 mg, 0.128 mmol) and tris(2-aminoethyl)amine (96 μL , 0.639 mmol) used as starting materials were prepared into compound **29** as a yellow gel (37.4 mg, 64%). ^1H NMR (400 MHz, CD_3OD) δ 7.28 (d, J = 8.6 Hz, 2H), 6.85 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.2 Hz, 1H), 6.08 (d, J = 16.2 Hz, 1H), 5.90 (dd, J = 17.5, 10.7 Hz, 1H), 5.12 (t, J = 7.2 Hz, 1H), 5.05–5.01 (m, 2H), 4.02 (t, J = 5.5 Hz, 2H), 3.18–3.01 (m, 8H), 2.87–2.72 (m, 6H), 2.00–1.82 (m, 6H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.44 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.44, 147.28, 136.62, 132.11, 132.00, 128.18 (2 $\times$ CH), 127.91, 125.92, 115.53 (2 $\times$ CH), 112.29, 68.13, 52.53 (2 $\times$ CH₂), 51.52, 46.28, 43.54 (3 $\times$ CH₂), 42.53, 38.07, 27.52, 25.89, 24.42, 24.34, 23.84, 17.67. HRMS (ESI⁺): calculated for $\text{C}_{28}\text{H}_{48}\text{N}_4\text{O}$ [M + H]⁺ 457.3906, found 457.3890.

Preparation of compound **30**

According to the method for synthesis of compound **24**, compound **2** (36.7 mg, 0.094 mmol) and 1,4,8,11-tetraazacyclotetradecane (147 μL , 0.75 mmol) used as starting materials were prepared into compound **30** as a yellow gel (29.8 mg, 62%). ^1H NMR (400 MHz, CD_3OD) δ 7.29 (d, J = 8.7

Hz, 2H), 6.87 (d, $J = 8.8$ Hz, 2H), 6.27 (d, $J = 16.3$ Hz, 1H), 6.09 (d, $J = 16.3$ Hz, 1H), 5.91 (dd, $J = 17.5$, 10.8 Hz, 1H), 5.15–5.10 (m, 1H), 5.05–4.99 (m, 2H), 4.08–3.98 (m, 2H), 3.58–3.35 (m, 2H), 3.24–3.09 (m, 6H), 2.99–2.50 (m, 10H), 2.00–1.64 (m, 13H), 1.57 (s, 3H), 1.50–1.44 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz,) δ 159.55, 147.28, 136.67, 132.09, 132.00, 128.22 (2 $\times$ CH), 127.89, 125.92, 115.56 (2 $\times$ CH), 112.30, 68.42, 54.07, 51.98, 51.76, 50.65, 50.44, 47.44 (2 $\times$ CH₂), 45.94, 45.76, 43.55, 42.54, 28.04, 25.89, 25.47, 24.35, 23.84, 23.36, 21.34, 17.68. HRMS ((ESI⁺): calculated for C₃₂H₅₄N₄O [M + H]⁺ 511.4376, found 511.4367.

Preparation of compound **31**

According to the method for synthesis of compound **24**, compound **2** (56 mg, 0.143 mmol) and 1,4,7,10,13-pentazacyclopentadecane (176.3 μL , 0.715 mmol) used as starting materials were prepared into compound **31** as a yellow gel (68.8 mg, 92%). ^1H NMR (400 MHz, CD₃OD) δ 7.26 (dd, $J = 8.5$, 3.4 Hz, 2H), 6.84 (dd, $J = 8.7$, 5.0 Hz, 2H), 6.24 (d, $J = 16.3$ Hz, 1H), 6.06 (dd, $J = 16.3$, 2.1 Hz, 1H), 5.88 (dd, $J = 17.5$, 10.8 Hz, 1H), 5.12–5.06 (m, 1H), 5.03–4.95 (m, 2H), 4.07–3.39 (m, 10H), 3.15–2.60 (m, 14H), 1.97–1.89 (m, 2H), 1.80–1.60 (m, 7H), 1.55 (s, 3H), 1.48–1.42 (m, 2H), 1.17 (s, 3H). ^{13}C NMR (100 MHz, CD₃OD) δ 159.55, 147.27, 136.70, 136.60, 132.00, 128.25, 128.20, 127.91, 127.87, 125.91, 115.52, 112.31, 68.66, 52.22, 51.95, 51.22, 48.04, 47.79, 46.85, 46.72, 46.22, 45.54, 45.09, 44.88, 43.55, 42.53, 28.23, 25.90, 24.34, 23.83, 22.49, 17.69. HRMS (ESI⁺): calculated for C₃₂H₅₅N₅O [M + H]⁺ 526.4485, found 526.4476.

Preparation of compound **32**

Compound **5** (31.7 mg, 0.089 mmol) was dissolved in methanol (8 mL). Then, iodomethane (1 mL) was added. The reaction mixture was stirred at room temperature over night. After the reaction, the reaction mixture was diluted with n-butanol and extracted twice with water. The organic phase was concentrated under reduced pressure. The crude product was purified by RP-HPLC, to afford compound **32** as a yellow gel (31.6 mg, 72%). ^1H NMR (400 MHz, CD₃OD) δ 7.29 (d, $J = 8.7$ Hz, 2H), 6.87 (d, $J = 8.7$ Hz, 2H), 6.27 (d, $J = 16.3$ Hz, 1H), 6.08 (d, $J = 16.3$ Hz, 1H), 5.90 (dd, $J = 17.5$, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.97 (m, 2H), 4.06 (t, $J = 5.9$ Hz, 2H), 3.46–3.38 (m, 2H), 3.14 (s, 9H), 2.04–1.82 (m, 6H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.45 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD₃OD) δ 159.38, 147.29, 136.72, 132.23, 131.99, 128.21 (2 $\times$ CH), 127.90, 125.94, 115.56 (2 $\times$ CH), 112.30, 67.93, 67.54, 53.54, 53.50, 53.46, 43.55, 42.54, 27.17, 25.88, 24.35, 23.84, 21.10, 17.67. HRMS (ESI⁺): calculated for C₂₅H₄₀INO [M - I]⁺ 370.3104, found 370.3105.

Preparation of compound **33**

According to the method for synthesis of compound **32**, compound **6** (31.3 mg, 0.082 mmol)

and iodomethane (1 mL) used as starting materials were prepared into compound **33** as a yellow gel (34.7 mg, 83%). ^1H NMR (400 MHz, CD_3OD) δ 7.29 (d, J = 8.7 Hz, 2H), 6.88 (d, J = 8.8 Hz, 2H), 6.27 (d, J = 16.3 Hz, 1H), 6.09 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.5, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.06–4.98 (m, 2H), 4.06 (t, J = 5.7 Hz, 2H), 3.41–3.31 (m, 6H), 3.00 (s, 3H), 1.99–1.83 (m, 6H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.45 (m, 2H), 1.36–1.31 (m, 6H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.34, 147.29, 136.76, 132.28, 131.99, 128.22 (2 $\times$ CH), 127.89, 125.94, 115.56 (2 $\times$ CH), 112.30, 67.89, 61.22, 57.61, 57.58, 57.54, 43.55, 42.54, 27.08, 25.88, 24.35, 23.85, 20.16, 17.67, 9.12, 8.01. HRMS (ESI $^+$): calculated for $\text{C}_{27}\text{H}_{44}\text{INO}$ [$\text{M} - \text{I}$] $^+$ 398.3417, found 398.3418.

Preparation of compound **34**

According to the method for synthesis of compound **32**, compound **7** (34.5 mg, 0.078 mmol) and iodomethane (1 mL) used as starting materials were prepared into compound **34** as a yellow oil (37 mg, 81%). ^1H NMR (400 MHz, CD_3OD) δ 7.27 (d, J = 8.8 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 6.24 (d, J = 16.3 Hz, 1H), 6.06 (d, J = 16.3 Hz, 1H), 5.88 (dd, J = 17.5, 10.8 Hz, 1H), 5.13–5.06 (m, 1H), 5.03–4.95 (m, 2H), 4.04 (t, J = 5.7 Hz, 2H), 3.36–3.30 (m, 2H), 3.28–3.21 (m, 4H), 3.00 (s, 3H), 1.98–1.78 (m, 6H), 1.73–1.61 (m, 7H), 1.54 (s, 3H), 1.49–1.34 (m, 6H), 1.18–1.15 (m, 3H), 0.97 (t, J = 7.4 Hz, 6H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.30, 147.28, 136.76, 132.29, 131.98, 128.24 (2 $\times$ CH), 127.88, 125.94, 115.56 (2 $\times$ CH), 112.30, 67.71, 62.71, 62.68, 62.65, 62.07, 43.55, 42.54, 26.96, 25.89, 25.12 (2 $\times$ CH $_2$), 24.35, 23.86, 20.74, 20.72, 20.14, 17.68, 13.93 (2 $\times$ CH $_3$). HRMS (ESI $^+$): calculated for $\text{C}_{31}\text{H}_{52}\text{INO}$ [$\text{M} - \text{I}$] $^+$ 454.4043, found 454.4043.

Preparation of compound **35**

According to the method for synthesis of compound **38**, **13** (45.6 mg, 0.139 mmol), 1H-pyrazole-1-carboxamidine hydrochloride (61.2 mg, 0.418 mmol) and DIPEA (138 μL , 0.835 mmol) used as starting materials were prepared into compound **35** as a yellow gel (30.6 mg, 55%). ^1H NMR (400 MHz, CD_3OD) δ 7.28 (d, J = 8.6 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.07 (d, J = 16.3 Hz, 1H), 5.90 (dd, J = 17.5, 10.8 Hz, 1H), 5.16–5.09 (m, 1H), 5.05–4.98 (m, 2H), 4.00 (t, J = 5.9 Hz, 2H), 3.25 (t, J = 6.9 Hz, 2H), 2.00–1.92 (m, 2H), 1.88–1.74 (m, 4H), 1.66 (s, 3H), 1.57 (s, 3H), 1.50–1.45 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 159.54, 158.70, 147.28, 136.55, 132.03, 131.97, 128.15 (2 $\times$ CH), 127.94, 125.92, 115.51 (2 $\times$ CH), 112.28, 68.36, 43.53, 42.53, 42.17, 27.46, 26.76, 25.88, 24.33, 23.84, 17.67. HRMS (ESI $^+$): calculated for $\text{C}_{23}\text{H}_{35}\text{N}_3\text{O}$ [$\text{M} + \text{H}$] $^+$ 370.2858, found 370.2849.

Preparation of compound **36**

Bakuchiol (93.5 mg, 0.357 mmol) was dissolved in acetone (10 mL). Then, potassium carbonate

(123.5 mg, 0.893 mmol) and ethyl bromoacetate (81 μ L, 0.081 mmol) were added. The reaction mixture was stirred under reflux for 3 h. After the reaction, the resulting mixture was diluted with ethyl acetate and extracted twice with water. The organic phase was concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (petroleum ether/ethyl acetate, 6: 1, v/v), to afford compound **36** as a pale yellow oil (114.1 mg, 93%). ^1H NMR (400 MHz, CDCl_3) δ 7.29 (d, J = 8.7 Hz, 2H), 6.85 (d, J = 8.8 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.08 (d, J = 16.3 Hz, 1H), 5.88 (dd, J = 17.4, 10.7 Hz, 1H), 5.14–5.07 (m, 1H), 5.06–4.98 (m, 2H), 4.61 (s, 2H), 4.27 (q, J = 7.1 Hz, 2H), 1.99–1.91 (m, 2H), 1.67 (s, 3H), 1.58 (s, 3H), 1.52–1.47 (m, 2H), 1.30 (t, J = 7.1 Hz, 3H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 169.03, 157.02, 145.96, 136.51, 131.85, 131.40, 127.31 (2 $\times$ CH), 126.43, 124.86, 114.80 (2 $\times$ CH), 112.02, 65.64, 61.46, 42.64, 41.35, 25.78, 23.42, 23.31, 17.72, 14.25. HRMS (ESI $^+$): calculated for $\text{C}_{22}\text{H}_{30}\text{O}_3$ [$\text{M} + \text{H}$] $^+$ 343.2273, found 343.2265.

Preparation of compound **38**

Compound **36** (121.8 mg, 0.356 mmol) was dissolved in tetrahydrofuran (10 mL). Then, a solution of LiOH (34.1 mg, 1.42 mmol) in water (5 mL) was added. The reaction mixture was stirred at room temperature for 0.5 hour. Then, the resulting mixture was acidified with acetic acid and extracted twice with n-butanol and water. The combined organic phase was concentrated under reduced pressure, to afford a crude product **37**. Compound **37** was directly used in the next reaction without further purification. Compound **37** was dissolved in anhydrous DMF (8 mL). Then, HATU (405.6 mg, 1.07 mmol), H-Arg-OMe 2HCl (278.6 mg, 1.07 mmol), HOBT (144.1 mg, 1.07 mmol), EDC HCl (204.5mg, 1.07mmol) and DIPEA (470.1 μ L, 2.84 mmol) were added. The reaction mixture was stirred at room temperature for 48 hours. After the reaction, the reaction mixture was extracted twice with n-butanol and water. The organic phase was concentrated under reduced pressure. The resulting crude product was purified by RP-HPLC, to afford compound **38** as a yellow gel (122.4 mg, 71%). ^1H NMR (400 MHz, CDCl_3) δ 8.15 (s, 1H), 7.59 (d, J = 8.0 Hz, 1H), 7.29 (d, J = 8.7 Hz, 2H), 7.07 (br, 3H), 6.86 (d, J = 8.7 Hz, 2H), 6.24 (d, J = 16.2 Hz, 1H), 6.07 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.5, 10.7 Hz, 1H), 5.09 (t, J = 7.1 Hz, 1H), 5.06–4.96 (m, 2H), 4.64–4.42 (m, 3H), 3.72 (s, 3H), 3.20 (d, J = 55.2 Hz, 2H), 2.01–1.91 (m, 6H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.45 (m, 2H), 1.18 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 173.31, 171.43, 158.65, 158.29, 147.19, 137.37, 133.23, 132.02, 128.28 (2 $\times$ CH), 127.71, 125.90, 115.96 (2 $\times$ CH), 112.37, 68.17, 52.94, 52.84, 43.59, 42.51, 41.77, 29.49, 26.23, 25.88, 24.34, 23.79, 17.67. HRMS (ESI $^+$): calculated for $\text{C}_{27}\text{H}_{40}\text{N}_4\text{O}_4$ [$\text{M} + \text{H}$] $^+$ 485.3128, found 485.3125.

Preparation of compound **39**

According to the method for synthesis of compound **38**, **36** (40.9 mg, 0.119 mmol), HATU (136 mg, 0.358 mmol), H-Arg-NH₂ 2HCl (93.9 mg, 0.358 mmol), HOBT (48.2 mg, 0.358 mmol), EDC HCl (68.4 mg, 0.358 mmol) and DIPEA (157.9 μ L, 0.955 mmol) used as starting materials were prepared into compound **39** as a yellow gel (30.6 mg, 55%). ¹H NMR (400 MHz, CD₃OD) δ 7.33 (d, J = 8.7 Hz, 2H), 6.94 (d, J = 8.8 Hz, 2H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.16–5.08 (m, 1H), 5.06–4.98 (m, 2H), 4.60–4.56 (m, 2H), 4.52–4.48 (m, 1H), 3.21–3.14 (m, 2H), 1.99–1.72 (m, 4H), 1.66 (s, 3H), 1.63–1.55 (m, 5H), 1.51–1.45 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 171.14, 158.63, 158.20, 147.19, 137.43, 133.29, 132.03, 128.33 (2 $\times$ CH), 127.70, 125.91, 115.93, 112.38, 101.33, 68.22, 53.31, 43.60, 42.51, 41.88, 30.52, 26.13, 25.87, 24.34, 23.80, 17.67. HRMS (ESI⁺): calculated for C₂₆H₃₉N₅O₃ [M + H]⁺ 470.3131, found 470.3127.

Preparation of compound **40**

According to the method for synthesis of compound **38**, **36** (99.6 mg, 0.291 mmol), HATU (221.2 mg, 0.582 mmol), H-His-OMe 2HCl (140.8 mg, 0.582 mmol), HOBT (78.4 mg, 0.582 mmol), EDC HCl (111.2 mg, 0.582 mmol) and DIPEA (288 μ L, 1.74 mmol) used as starting materials were prepared into compound **40** as a yellow gel (87.4 mg, 64%). ¹H NMR (400 MHz, CD₃OD) δ 7.94 (s, 1H), 7.31 (d, J = 8.7 Hz, 2H), 6.98–6.84 (m, 3H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.15–5.08 (m, 1H), 5.07–4.98 (m, 2H), 4.83–4.79 (m, 1H), 4.54–4.46 (m, 2H), 3.72 (s, 3H), 3.26–3.09 (m, 2H), 2.00–1.92 (m, 2H), 1.66 (s, 3H), 1.57 (s, 3H), 1.51–1.46 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 171.02, 169.03, 156.31, 145.80, 136.84, 134.51, 132.11, 131.46, 130.82, 127.41 (2 $\times$ CH), 126.20, 124.78, 116.80, 114.87 (2 $\times$ CH), 112.14, 67.23, 52.96, 51.77, 42.66, 41.28, 28.11, 25.83, 23.28, 23.24, 17.76. HRMS ((ESI⁺): calculated for C₂₇H₃₅N₃O₄ [M + H]⁺ 466.2706, found 466.2698.

Preparation of compound **41**

According to the method for synthesis of compound **38**, **36** (50 mg, 0.146 mmol), HATU (111 mg, 0.292 mmol), H-Lys(Boc)-OMe HCl (108.3 mg, 0.365 mmol), HOBT (39.3 mg, 0.292 mmol), EDC HCl (55.8 mg, 0.292 mmol) and DIPEA (144.8 μ L, 0.876 mmol) used as starting materials were prepared into compound **41** as a yellow gel (72.5 mg, 82%). ¹H NMR (400 MHz, CDCl₃) δ 7.30 (d, J = 8.8 Hz, 2H), 7.04 (d, J = 8.3 Hz, 1H), 6.87 (d, J = 8.8 Hz, 2H), 6.25 (d, J = 16.3 Hz, 1H), 6.08 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.5, 10.7 Hz, 1H), 5.13–4.94 (m, 3H), 4.72–4.60 (m, 1H), 4.57–4.44 (m, 3H), 3.73 (s, 3H), 3.10–2.98 (m, 2H), 1.96–1.71 (m, 4H), 1.65 (s, 3H), 1.56 (s,

3H), 1.50–1.43 (m, 4H), 1.41 (s, 9H), 1.31–1.23 (m, 2H), 1.18 (s, 3H). HRMS (ESI⁺): calculated for C₃₂H₄₈N₂O₆ [M + Na]⁺ 579.3410, found 579.3398.

Preparation of compound **42**

According to the method for synthesis of compound **44**, **36** (48 mg, 0.14 mmol), HATU (133.9 mg, 0.352 mmol), H-Ala-OMe HCl (59 mg, 0.423 mmol) and DIPEA (186 μ L, 1.13 mmol) used as starting materials were prepared into a crude product which is compound **42**. After the reaction, the resulting mixture was diluted with ethyl acetate and extracted twice with water. The organic phase was concentrated under reduced pressure. The crude product was purified by silica gel column chromatography (petroleum ether/ethyl acetate, 2: 1, v/v), to afford compound **42** as a colorless clear gel (45.2 mg, 81%). ¹H NMR (400 MHz, CDCl₃) δ 7.32 (d, *J* = 8.8 Hz, 2H), 7.13 (d, *J* = 7.6 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 2H), 6.26 (d, *J* = 16.3 Hz, 1H), 6.09 (d, *J* = 16.3 Hz, 1H), 5.87 (dd, *J* = 17.4, 10.7 Hz, 1H), 5.15–5.07 (m, 1H), 5.06–4.96 (m, 2H), 4.76–4.63 (m, 1H), 4.49 (s, 2H), 3.76 (s, 3H), 1.99–1.90 (m, 2H), 1.67 (s, 3H), 1.58 (s, 3H), 1.51–1.45 (m, 5H), 1.19 (s, 3H). ¹³C NMR (100 MHz, CDCl₃) δ 173.07, 167.93, 156.28, 145.85, 136.84, 132.22, 131.47, 127.47 (2 $\times$ CH), 126.26, 124.81, 114.87 (2 $\times$ CH), 112.12, 67.41, 52.71, 47.70, 42.68, 41.32, 25.82, 23.33, 23.30, 18.48, 17.75. HRMS (ESI⁺): calculated for C₂₄H₃₃NO₄ [M + H]⁺ 400.2488, found 400.2471.

Preparation of compound **43**

According to the method for synthesis of compound **44**, **36** (79.5 mg, 0.232 mmol), HATU (176.5 mg, 0.464 mmol), H-Lys(Fmoc)-OH HCl (243.1 mg, 0.58 mmol) and DIPEA (230 μ L, 1.39 mmol) used as starting materials were prepared into compound **43** as a colorless clear gel (155.5 mg, 98%). HRMS (ESI⁺): calculated for C₄₂H₅₀N₂O₆ [M + H]⁺ 679.3747, found 679.3727.

Preparation of compound **44**

According to the method for synthesis of compound **38**, **36** (89.3 mg, 0.261 mmol), HATU (198.3 mg, 0.522 mmol), H-Arg-Arg-OMe 2HCl (217.7 mg, 0.522 mmol) and DIPEA (174 μ L, 1.04 mmol) used as starting materials were prepared into compound **44** as a white colloidal solid (166 mg, 98%). ¹H NMR (400 MHz, CD₃OD) δ 7.33 (d, *J* = 8.8 Hz, 2H), 6.93 (d, *J* = 8.8 Hz, 2H), 6.28 (d, *J* = 16.3 Hz, 1H), 6.12 (d, *J* = 16.3 Hz, 1H), 5.91 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.07–4.98 (m, 2H), 4.58 (s, 2H), 4.52–4.44 (m, 2H), 3.73 (s, 3H), 3.25–3.12 (m, 4H), 2.01–1.86 (m, 4H), 1.83–1.62 (m, 9H), 1.57 (s, 3H), 1.52–1.45 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 173.80, 173.51, 171.21, 158.69, 158.24 (2 $\times$ C), 147.19, 137.46, 133.28, 132.05, 128.33 (2 $\times$ CH), 127.68, 125.90, 115.91 (2 $\times$ CH), 112.39, 68.08, 53.94, 53.17, 52.90, 43.60, 42.51, 41.93, 41.78, 30.28, 29.49, 26.17, 26.08, 25.87, 24.34, 23.79, 17.67. HRMS (ESI⁺): calculated for

$C_{33}H_{52}N_8O_5$ $[M + H]^+$ 641.4139, found 641.4130.

Preparation of compound **45**

According to the method for synthesis of compound **44**, **36** (54.7 mg, 0.160 mmol), HATU (121.7 mg, 0.32 mmol), H-Arg-Arg-Arg-OMe 2HCl (160.2 mg, 0.32 mmol) and DIPEA (158.4 μ L, 0.96 mmol) used as starting materials were prepared into compound **45** as a white gel (118.5 mg, 93%). 1H NMR (400 MHz, CD_3OD) δ 7.33 (d, J = 8.8 Hz, 2H), 6.93 (d, J = 8.8 Hz, 2H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.98 (m, 2H), 4.59 (s, 2H), 4.49–4.36 (m, 3H), 3.72 (s, 3H), 3.22–3.16 (m, 6H), 1.98–1.63 (m, 17H), 1.57 (s, 3H), 1.52–1.45 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 174.00, 173.78, 173.58, 171.42, 158.65, 158.22 (3 $\times$ C), 147.16, 137.41, 133.20, 132.03, 128.33, 127.66, 125.88, 115.86 (2 $\times$ CH), 112.40, 101.32, 68.02, 54.23, 54.12, 53.30, 52.87, 43.59, 42.49, 41.90, 41.85, 41.80, 30.11, 30.06, 29.41, 26.21, 26.15, 26.11, 25.88, 24.33, 23.75, 17.67. HRMS (ESI $^+$): calculated for $C_{39}H_{64}N_{12}O_6$ $[M + H]^+$ 797.5150, found 797.5121.

Preparation of compound **46**

According to the method for synthesis of compound **42**, **36** (48 mg, 0.14 mmol), HATU (160.7 mg, 0.423 mmol), H-Met-OMe HCl (84.4 mg, 0.423 mmol) and DIPEA (186 μ L, 1.13 mmol) used as starting materials were prepared into compound **46** as a colorless clear gel (50.4 mg, 78%). 1H NMR (400 MHz, $CDCl_3$) δ 7.30 (d, J = 8.8 Hz, 2H), 7.23 (d, J = 8.2 Hz, 1H), 6.86 (d, J = 8.8 Hz, 2H), 6.25 (d, J = 16.3 Hz, 1H), 6.08 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.5, 10.7 Hz, 1H), 5.13–5.05 (m, 1H), 5.04–4.97 (m, 2H), 4.84–4.74 (m, 1H), 4.50 (s, 2H), 3.75 (s, 3H), 2.53–2.43 (m, 2H), 2.25–1.89 (m, 7H), 1.66 (s, 3H), 1.56 (s, 3H), 1.51–1.45 (m, 2H), 1.18 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.01, 168.32, 156.23, 145.84, 136.89, 132.28, 131.47, 127.49 (2 $\times$ CH), 126.23, 124.80, 114.83 (2 $\times$ CH), 112.13, 67.39, 52.78, 51.12, 42.68, 41.32, 31.54, 29.95, 25.82, 23.33, 23.30, 17.75, 15.54. HRMS (ESI $^+$): calculated for $C_{26}H_{37}NO_4S$ $[M + H]^+$ 460.2522, found 460.2507.

Preparation of compound **47**

43 (76 mg, 0.112 mmol) was dissolved in anhydrous DMF (4 mL). Then, piperidine (1 mL) was added. The reaction mixture was stirred at room temperature for 0.5 h. After the reaction, the resulting mixture was diluted with n-butanol and extracted twice with water. The organic phase was concentrated under reduced pressure. The crude product was purified by RP-HPLC, to afford compound **47** as a yellow gel (38.2 mg, 75%). 1H NMR (400 MHz, $CDCl_3$) δ 7.32 (dd, J = 19.6, 8.5 Hz, 3H), 6.86 (d, J = 8.7 Hz, 2H), 6.24 (d, J = 16.2 Hz, 1H), 6.08 (d, J = 16.2 Hz, 1H), 5.86 (dd, J = 17.4, 10.8 Hz, 1H), 5.09 (t, J = 7.1 Hz, 1H), 5.06–4.97 (m, 2H), 4.70–4.59 (m, 1H), 4.57–4.40 (m,

2H), 3.77–3.67 (m, 3H), 2.88 (s, 2H), 1.98–1.62 (m, 9H), 1.57 (s, 3H), 1.52–1.34 (m, 4H), 1.18 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 172.28, 168.63, 156.25, 145.82, 136.86, 132.22, 131.46, 127.46 (2 $\times$ CH), 126.23, 124.79, 114.94 (2 $\times$ CH), 112.13, 67.32, 52.76, 51.48, 42.67, 41.30, 39.19, 31.97, 27.08, 25.83 (2 $\times$ CH₂), 23.29, 22.46, 17.76. HRMS (ESI⁺): calculated for $\text{C}_{27}\text{H}_{40}\text{N}_2\text{O}_4$ [$\text{M} + \text{H}$]⁺ 457.3066, found 457.3050.

Preparation of compound **49**

According to the method for synthesis of compound **38**, **38** (43.2 mg, 0.092 mmol), HATU (69.9 mg, 0.184 mmol), H-Arg-NH₂ 2HCl (45.2 mg, 0.184 mmol), HOBT (24.8 mg, 0.184 mmol), EDC HCl (35.2 mg, 0.184 mmol) and DIPEA (91.9 μL , 0.551 mmol) used as starting materials were prepared into compound **49** as a yellow gel (26.6 mg, 47%). ^1H NMR (400 MHz, CD_3OD) δ 7.33 (d, J = 8.8 Hz, 2H), 6.93 (d, J = 8.8 Hz, 2H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.99 (m, 2H), 4.58 (s, 2H), 4.50–4.45 (m, 1H), 4.42–4.36 (m, 1H), 3.21–3.15 (m, 4H), 2.01–1.74 (m, 6H), 1.69–1.61 (m, 7H), 1.57 (s, 3H), 1.52–1.45 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 176.28, 173.66, 171.35, 158.70, 158.25 (2 $\times$ C), 147.18, 137.44, 133.25, 132.04, 128.33 (2 $\times$ CH), 127.68, 125.90, 115.92 (2 $\times$ CH), 112.39, 68.11, 54.06, 53.89, 43.60, 42.51, 41.88, 41.86, 30.36, 30.10, 26.23, 26.03, 25.87, 24.34, 23.80, 17.67. HRMS (ESI⁺): calculated for $\text{C}_{32}\text{H}_{51}\text{N}_9\text{O}_4$ [$\text{M} + \text{H}$]⁺ 626.4142, found 626.4135.

Preparation of compound **50**

According to the method for synthesis of compound **49**, **38** (93 mg, 0.192 mmol), HATU (218.9 mg, 0.576 mmol), H-His-OMe 2HCl (139.4 mg, 0.576 mmol), HOBT (77.6 mg, 0.576 mmol), EDC HCl (110.1 mg, 0.576 mmol) and DIPEA (190.3 μL , 1.15 mmol) used as starting materials were prepared into compound **50** as a yellow gel (60.6 mg, 51%). ^1H NMR (400 MHz, CD_3OD) δ 7.72 (s, 1H), 7.33 (d, J = 8.8 Hz, 2H), 6.93 (d, J = 8.7 Hz, 3H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.99 (m, 2H), 4.73–4.67 (m, 1H), 4.56 (s, 2H), 4.53–4.48 (m, 1H), 3.71 (s, 3H), 3.20–3.02 (m, 4H), 2.01–1.70 (m, 4H), 1.66 (s, 3H), 1.63–1.56 (m, 5H), 1.51–1.46 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 173.51, 172.65, 171.12, 168.75, 158.60, 158.20, 158.17, 147.16, 137.36, 135.88, 133.19, 133.01, 132.04, 128.33, 127.66, 125.88, 118.33, 115.88, 112.40, 68.06, 53.68, 53.02, 43.60, 42.49, 41.83, 38.88, 30.22, 28.99, 26.02, 25.90, 24.33, 23.73, 17.68. HRMS (ESI⁺): calculated for $\text{C}_{33}\text{H}_{47}\text{N}_7\text{O}_5$ [$\text{M} + \text{H}$]⁺ 622.3717, found 622.3692.

Preparation of compounds **65** and **51**

Compound **38** (63.7 mg, 0.131 mmol) was dissolved in anhydrous DMF (8 mL). Then, HATU (124.9 mg, 0.329 mmol), H-Lys(Fmoc)-OH HCl (137.7 mg, 0.329 mmol) and DIPEA (130 μ L, 0.789 mmol) were added. According to the method for synthesis of compound **43**, compound **65** was prepared. After the reaction, the reaction mixture was extracted twice with n-butanol and water. The organic phase was concentrated under reduced pressure. Compound **65** was used in the next reaction without further purification. Subsequently, the crude product **65** was dissolved in anhydrous DMF (4 mL). Piperidine (1 mL) was added. According to the method for synthesis of **47**, **51** was prepared as an orange gel (44.5 mg, 55%). ^1H NMR (400 MHz, CD_3OD) δ 7.33 (d, J = 8.8 Hz, 2H), 6.93 (d, J = 8.8 Hz, 2H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.14–5.09 (m, 1H), 5.07–5.00 (m, 2H), 4.58 (s, 2H), 4.50–4.42 (m, 2H), 3.72 (s, 3H), 3.25–3.17 (m, 2H), 2.92–2.82 (m, 2H), 2.01–1.89 (m, 4H), 1.78–1.62 (m, 9H), 1.57 (s, 3H), 1.52–1.45 (m, 4H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 173.89, 173.75, 171.25, 158.66, 158.24 (2 $\times$ C), 147.17, 137.38, 133.18, 132.04, 128.34 (2 $\times$ CH), 127.66, 125.88, 115.87 (2 $\times$ CH), 112.40, 67.97, 54.04, 53.17, 52.86, 43.60, 42.50, 41.87, 40.40, 31.67, 30.19, 27.78, 26.08, 25.90, 24.34, 23.73, 23.69, 17.68. HRMS (ESI $^+$): calculated for $\text{C}_{33}\text{H}_{52}\text{N}_6\text{O}_5$ [$\text{M} + \text{H}$] $^+$ 613.4077, found 613.4056.

Preparation of compound **52**

According to the method for synthesis of compound **38**, **38** (40 mg, 0.083 mmol), HATU (62.8 mg, 0.165 mmol), *N,N*-diethyl-1,3-propanediamine (78.1 μ L, 0.495 mmol) and DIPEA (68.2 μ L, 0.413 mmol) used as starting materials were prepared into compound **52** as a yellow gel (43.2 mg, 89%). ^1H NMR (400 MHz, CDCl_3) δ 7.29 (d, J = 8.5 Hz, 2H), 6.90 (d, J = 8.4 Hz, 2H), 6.25 (d, J = 16.3 Hz, 1H), 6.09 (d, J = 16.3 Hz, 1H), 5.87 (dd, J = 17.5, 10.8 Hz, 1H), 5.08 (t, J = 7.2 Hz, 1H), 5.02–4.95 (m, 2H), 4.56 (s, 2H), 4.32–4.26 (m, 1H), 3.28–3.26 (m, 2H), 3.17–3.02 (m, 8H), 1.97–1.69 (m, 6H), 1.68–1.55 (m, 5H), 1.54 (s, 3H), 1.48–1.42 (m, 2H), 1.23 (t, J = 7.3 Hz, 6H), 1.16 (s, 3H). ^{13}C NMR (100 MHz, CDCl_3) δ 172.59 (2 $\times$ C), 156.81, 156.48, 145.79, 136.69, 131.87, 131.42, 127.40, 126.23, 124.78, 114.94, 114.91, 112.10, 100.00, 60.53, 58.51, 58.44, 50.85 (2 $\times$ CH_2), 46.34, 42.63 (2 $\times$ CH_2), 41.27, 25.81 (2 $\times$ CH_2), 23.28, 23.21, 21.18, 17.75, 14.29, 8.43 (2 $\times$ CH_3). HRMS (ESI $^+$): calculated for $\text{C}_{33}\text{H}_{54}\text{N}_6\text{O}_3$ [$\text{M} + \text{H}$] $^+$ 583.4336, found 583.4327.

Preparation of compound **53**

According to the method for synthesis of compound **38**, **38** (48 mg, 0.101 mmol), HATU (115.3 mg, 0.303 mmol), (S)-N-((3-(3-fluoro-4-piperazin-1-ylphenyl)-2-oxooxazolidin-5-yl)methyl)-acetamide (85.0 mg,

0.253 mmol), HOBT (46.4 mg, 0.303 mmol), EDC HCl (58.3 mg, 0.303 mmol) and DIPEA (133.7 μ L, 0.809 mmol) used as starting materials were prepared into compound **53** as a yellow gel (32.4 mg, 41%). ^1H NMR (400 MHz, CD_3OD) δ 7.50 (dd, J = 14.5, 2.5 Hz, 1H), 7.32 (d, J = 8.7 Hz, 2H), 7.17 (d, J = 8.7 Hz, 1H), 7.03 (t, J = 9.1 Hz, 1H), 6.94 (d, J = 8.8 Hz, 2H), 6.27 (d, J = 16.3 Hz, 1H), 6.11 (d, J = 16.3 Hz, 1H), 5.89 (dd, J = 17.5, 10.8 Hz, 1H), 5.14–5.09 (m, 1H), 5.05–4.97 (m, 3H), 4.83–4.74 (m, 2H), 4.61–4.56 (m, 2H), 4.11 (t, J = 9.0 Hz, 1H), 3.92–3.75 (m, 3H), 3.73–3.61 (m, 2H), 3.55 (d, J = 5.0 Hz, 2H), 3.28–3.14 (m, 2H), 3.10–2.93 (m, 4H), 1.99–1.74 (m, 7H), 1.67–1.60 (m, 5H), 1.57 (s, 3H), 1.50–1.45 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 174.06, 171.20, 170.77, 158.61, 158.17, 158.03, 156.56, 155.59, 147.17, 137.45, 137.00, 135.38, 133.30, 132.03, 128.35, 127.66, 125.90, 120.85, 115.97, 115.49, 112.40, 108.55, 108.29, 73.46, 68.16, 49.85, 48.34 ($2\times\text{CH}_2$), 46.95, 43.59 ($2\times\text{CH}_2$), 43.52, 43.14, 42.49, 41.96, 30.28, 25.89 ($2\times\text{CH}_3$), 24.34, 23.78, 22.46, 17.69.

Preparation of compound **55**

According to the method for synthesis of compound **40**, **40** (66.4 mg, 0.143 mmol), HATU (108.5 mg, 0.285 mmol), H-His-OMe 2HCl (86.3 mg, 0.357 mmol), HOBT (38.4 mg, 0.285 mmol), EDC HCl (54.5 mg, 0.285 mmol) and DIPEA (141.4 μ L, 0.856 mmol) used as starting materials were prepared into compound **55** as a yellow gel (41.2 mg, 48%). ^1H NMR (400 MHz, CD_3OD) δ 8.28 (d, J = 9.4 Hz, 2H), 8.11 (d, J = 40.2 Hz, 2H), 7.28 (d, J = 8.8 Hz, 2H), 7.07 (d, J = 25.4 Hz, 2H), 6.85 (d, J = 8.7 Hz, 2H), 6.17 (dd, J = 64.9, 16.3 Hz, 2H), 5.88 (dd, J = 17.5, 10.8 Hz, 1H), 5.12–4.94 (m, 4H), 4.74–4.64 (m, 2H), 4.55–4.41 (m, 2H), 3.70 (s, 3H), 3.19–3.06 (m, 2H), 2.78 (s, 2H), 1.98–1.89 (m, 2H), 1.63 (s, 3H), 1.54 (s, 3H), 1.49–1.41 (m, 2H), 1.17 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 172.47, 172.35, 171.08, 158.18, 147.18, 137.45, 135.76, 135.63, 133.24, 132.74, 132.03, 132.00, 128.31, 127.68, 125.90, 118.32, 118.16, 115.90, 115.87, 112.38, 97.37, 68.14, 53.66, 53.09, 43.60, 42.50, 38.88, 29.25, 28.52, 25.87, 24.34, 23.78, 17.67. HRMS (ESI⁺): calculated for $\text{C}_{33}\text{H}_{42}\text{N}_6\text{O}_5$ $[\text{M} + \text{H}]^+$ 603.3295, found 603.3278.

Preparation of compounds **66** and **56**

According to the method for synthesis of compound **51**, **40** (89.9 mg, 0.193 mmol), HATU (220.1 mg, 0.597 mmol), H-Lys(Fmoc)-OH HCl (242.7 mg, 0.597 mmol) and DIPEA (255 μ L, 1.54 mmol) used as starting materials were prepared into compound **56** as a yellow gel (39.5 mg, 35%). ^1H NMR (400 MHz, CD_3OD) δ 7.82 (s, 1H), 7.31 (d, J = 8.7 Hz, 2H), 6.98 (s, 1H), 6.88 (d, J = 8.8 Hz, 2H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.5, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.08–5.02 (m, 2H), 4.70–4.63 (m, 1H), 4.55–4.43 (m, 3H), 3.74–3.69 (m, 3H),

3.19–3.03 (m, 2H), 2.91–2.83 (m, 2H), 1.98–1.92 (m, 2H), 1.77–1.55 (m, 10H), 1.52–1.42 (m, 4H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 173.64, 173.24, 171.21, 158.21, 147.17, 137.35, 136.19, 133.14, 132.04, 128.31 (2 $\times$ CH), 127.69, 125.88, 117.97, 115.86 (2 $\times$ CH), 112.40, 101.32, 67.99, 54.49, 53.11, 52.86, 43.60, 42.50, 40.41, 31.79, 29.93, 27.77, 25.90, 24.34, 23.74, 23.57, 17.69. HRMS ((ESI $^{+}$)): calculated for $\text{C}_{33}\text{H}_{47}\text{N}_5\text{O}_5$ [$\text{M} + \text{H}$] $^{+}$ 594.3655, found 594.3637.

Preparation of compound **58**

According to the method for synthesis of compound **38**, **44** (74.7 mg, 0.119 mmol), HATU (135.9 mg, 0.358 mmol), H-Arg-NH $_2$ 2HCl (93.7 mg, 0.358 mmol), HOBT (47.6 mg, 0.358 mmol), EDC HCl (68.5 mg, 0.358 mmol) and DIPEA (157.6 μL , 0.953 mmol) used as starting materials were prepared into compound **58** as a yellow gel (66.6 mg, 70%). ^1H NMR (400 MHz, CD_3OD) δ 7.33 (d, J = 8.7 Hz, 2H), 6.93 (d, J = 8.7 Hz, 2H), 6.28 (d, J = 16.3 Hz, 1H), 6.12 (d, J = 16.3 Hz, 1H), 5.91 (dd, J = 17.4, 10.8 Hz, 1H), 5.12 (t, J = 7.2 Hz, 1H), 5.07–4.92 (m, 3H), 4.59 (s, 2H), 4.49–4.32 (m, 3H), 3.22–3.15 (m, 6H), 2.00–1.73 (m, 8H), 1.66 (s, 9H), 1.57 (s, 3H), 1.51–1.46 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 176.33, 173.84, 171.47, 169.92, 158.69, 158.24 (3 $\times$ C), 147.17, 137.43, 133.22, 132.04, 128.33, 127.67, 125.89, 115.89 (2 $\times$ CH), 112.40, 101.33, 68.08, 54.48, 54.25, 53.93, 43.60 (3 $\times$ CH $_2$), 42.50, 41.84, 30.42, 30.07, 29.87, 26.24, 26.14, 25.88, 24.34 (2 $\times$ CH $_2$), 23.77, 17.68. HRMS (ESI $^{+}$): calculated for $\text{C}_{38}\text{H}_{63}\text{N}_{13}\text{O}_5$ [$\text{M} + \text{H}$] $^{+}$ 782.5153, found 782.5142.

Preparation of compound **59**

According to the method for synthesis of compound **38**, **44** (38.9 mg, 0.061 mmol), HATU (69.3 mg, 0.182 mmol), (S)-N-((3-(3-fluoro-4-piperazin-1-yl)phenyl)-2-oxooxazolidin-5-yl)methyl)-acetamide (40.9 mg, 0.122 mmol), HOBT (27.9 mg, 0.182 mmol), EDC HCl (35.7 mg, 0.182 mmol) and DIPEA (80.3 μL , 0.486 mmol) used as starting materials were prepared into compound **59** as a yellow gel (23.2 mg, 41%). ^1H NMR (400 MHz, CD_3OD) δ 7.51 (d, J = 14.6 Hz, 1H), 7.33 (d, J = 8.6 Hz, 2H), 7.18 (d, J = 8.9 Hz, 1H), 7.09–7.01 (m, 1H), 6.93 (d, J = 6.6 Hz, 2H), 6.28 (d, J = 16.4 Hz, 1H), 6.13 (d, J = 16.3 Hz, 1H), 5.97–5.82 (m, 1H), 5.16–5.09 (m, 1H), 5.08–4.95 (m, 3H), 4.79–4.46 (m, 3H), 4.11 (t, J = 9.2 Hz, 1H), 3.88–3.50 (m, 6H), 3.30–2.84 (m, 10H), 2.05–1.72 (m, 8H), 1.72–1.53 (m, 11H), 1.51–1.43 (m, 2H), 1.20 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 174.10, 173.42, 171.61, 171.26, 169.98, 158.68, 158.25, 158.24, 156.61, 147.17 (2 $\times$ CH), 137.43, 137.04, 134.99, 133.22, 132.05, 128.34 (2 $\times$ CH), 127.67, 125.89 (2 $\times$ CH), 115.89 (2 $\times$ CH), 113.39, 112.40, 73.50, 53.95, 50.16, 49.71, 48.34 (2 $\times$ CH $_2$), 48.33 (2 $\times$ CH $_2$), 48.32, 43.60, 43.13, 42.50, 41.91, 41.84, 30.22, 29.92,

25.96, 25.88 (2×CH₂), 24.34, 23.78, 22.44, 17.68. HRMS (ESI⁺): calculated for C₄₈H₆₉FN₁₂O₇ [M + H]⁺ 945.5474, found 945.5457.

Preparation of compound **60**

According to the method for synthesis of compound **44**, **44** (52.6 mg, 0.084 mmol), HATU (63.8 mg, 0.168 mmol), H-Arg-Arg-OMe 2HCl (70.1 mg, 0.168 mmol) and DIPEA (55.5 μL, 0.336 mmol) used as starting materials were prepared into compound **60** as a white foam (43.3 mg, 55%). ¹H NMR (400 MHz, CD₃OD) δ 7.32 (d, *J* = 8.7 Hz, 2H), 6.93 (d, *J* = 8.7 Hz, 2H), 6.28 (d, *J* = 16.3 Hz, 1H), 6.12 (d, *J* = 16.3 Hz, 1H), 5.91 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.12 (t, *J* = 7.2 Hz, 1H), 5.06–4.98 (m, 2H), 4.60 (s, 2H), 4.45–4.34 (m, 4H), 3.72 (s, 3H), 3.23–3.15 (m, 8H), 1.99–1.86 (m, 6H), 1.83–1.70 (m, 6H), 1.69–1.61 (m, 9H), 1.57 (s, 3H), 1.51–1.46 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 174.08, 173.97, 173.86, 173.59, 171.51, 158.68 (2×C), 158.67 (2×C), 158.22, 147.15, 137.40, 133.19, 132.03, 128.32 (2×CH), 127.65, 125.88, 115.87 (2×CH), 112.39, 68.04, 54.39, 54.28, 54.25, 53.36, 52.88, 43.59 (2×CH₂), 42.48, 41.92, 41.85, 41.80, 30.16, 29.98, 29.89, 29.40, 26.28, 26.17, 26.15, 26.13, 25.88, 24.33, 23.74, 17.67. HRMS (ESI⁺): calculated for C₄₅H₇₆N₁₆O₇ [M + 2H]²⁺ 477.3120, found 477.3114.

Preparation of compound **61**

According to the method for synthesis of compound **60**, **44** (67.2 mg, 0.107 mmol), HATU (101.9 mg, 0.268 mmol), H-Arg-Arg-NH₂ 2HCl (107.8 mg, 0.268 mmol) and DIPEA (141.8 μL, 0.858 mmol) used as starting materials were prepared into compound **61** as a yellow gel (56.8 mg, 57%). ¹H NMR (400 MHz, CD₃OD) δ 7.33 (d, *J* = 8.8 Hz, 2H), 6.93 (d, *J* = 8.8 Hz, 2H), 6.28 (d, *J* = 16.3 Hz, 1H), 6.12 (d, *J* = 16.3 Hz, 1H), 5.91 (dd, *J* = 17.5, 10.8 Hz, 1H), 5.15–5.09 (m, 1H), 5.06–4.99 (m, 2H), 4.60 (s, 2H), 4.47–4.41 (m, 1H), 4.38–4.31 (m, 3H), 3.22–3.16 (m, 8H), 2.00–1.85 (m, 6H), 1.82–1.72 (m, 4H), 1.70–1.62 (m, 11H), 1.57 (s, 3H), 1.51–1.46 (m, 2H), 1.20 (s, 3H). ¹³C NMR (100 MHz, CD₃OD) δ 176.35, 174.12, 174.09, 173.89, 171.56, 169.99, 158.69 (4×C), 158.24, 147.16, 137.45, 133.23, 132.04, 128.33 (2×CH), 127.66, 125.89, 115.88 (2×CH), 112.40, 68.08, 54.57, 54.50, 54.39, 54.00, 43.60 (3×CH₂), 42.50, 41.89, 41.84, 30.41, 29.99, 29.96, 29.85, 26.31, 26.23, 26.18, 26.12, 25.88, 24.34, 23.76, 17.67. HRMS (ESI⁺): calculated for C₄₄H₇₅N₁₇O₆ [M + 2H]²⁺ 469.8122, found 469.8108.

Preparation of compound **63**

According to the method for synthesis of compound **38**, **45** (47 mg, 0.059 mmol), HATU (67.3 mg, 0.177 mmol), (S)-N-((3-(3-fluoro-4-piperazin-1-ylphenyl)-2-oxooxazolidin-5-yl)methyl)-acetamide (49.6 mg,

0.147 mmol), HOBt (27.1 mg, 0.177 mmol), EDC HCl (33.8 mg, 0.177 mmol) and DIPEA (78 μ L, 0.472 mmol) used as starting materials were prepared into compound **63** as a yellow gel (18.5 mg, 28%). ^1H NMR (400 MHz, CD_3OD) δ 7.53–7.43 (m, 1H), 7.30 (d, J = 8.8 Hz, 2H), 7.15 (d, J = 8.2 Hz, 1H), 7.03 (t, J = 9.1 Hz, 1H), 6.90 (d, J = 8.7 Hz, 2H), 6.25 (d, J = 16.3 Hz, 1H), 6.09 (d, J = 16.3 Hz, 1H), 5.88 (dd, J = 17.5, 10.8 Hz, 1H), 5.09 (t, J = 7.2 Hz, 1H), 5.03–4.96 (m, 2H), 4.82–4.70 (m, 2H), 4.61–4.53 (m, 2H), 4.47–4.34 (m, 2H), 4.12–4.02 (m, 1H), 3.84–3.64 (m, 4H), 3.55–3.48 (m, 2H), 3.25–3.12 (m, 6H), 3.10–2.82 (m, 5H), 1.97–1.57 (m, 20H), 1.54 (s, 3H), 1.49–1.42 (m, 2H), 1.17 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 174.08, 173.86, 173.56, 171.62, 171.40, 170.11, 158.71, 158.23, 158.22, 156.60, 155.61, 147.15, 137.45, 133.21, 132.04, 128.33, 127.65, 125.88, 120.91, 115.93, 115.91, 115.57, 115.53, 112.41, 108.60, 108.34, 101.31, 73.47, 68.09, 54.34, 54.14, 52.48, 52.21, 51.13, 51.10, 50.16 ($2\times\text{CH}_2$), 43.59 ($2\times\text{CH}_2$), 43.13, 42.48, 41.93, 41.84, 30.12, 30.02, 29.96, 26.19, 26.13, 25.98, 25.88, 24.33, 23.77, 22.46, 17.68.

Preparation of compound **64**

According to the method for synthesis of compound **60**, **45** (53.9 mg, 0.068 mmol), HATU (51.4 mg, 0.135 mmol), H-Arg-Arg-Arg-OMe 2HCl (67.7 mg, 0.135 mmol) and DIPEA (67.1 μ L, 0.407 mmol) used as starting materials were prepared into compound **64** as a yellow gel (12.9 mg, 16%). ^1H NMR (400 MHz, CD_3OD) δ 7.30 (d, J = 8.7 Hz, 2H), 6.90 (d, J = 8.7 Hz, 2H), 6.26 (d, J = 16.3 Hz, 1H), 6.10 (d, J = 16.3 Hz, 1H), 5.88 (dd, J = 17.5, 10.8 Hz, 1H), 5.13–5.06 (m, 1H), 5.05–4.95 (m, 2H), 4.58 (s, 2H), 4.42–4.29 (m, 6H), 3.69 (s, 3H), 3.21–3.14 (m, 12H), 1.96–1.82 (m, 8H), 1.80–1.60 (m, 21H), 1.55 (s, 3H), 1.49–1.42 (m, 2H), 1.17 (s, 3H). ^{13}C NMR (100 MHz, CD_3OD) δ 174.26, 174.14, 173.97, 173.60, 173.01, 171.69, 170.23, 158.67 ($6\times\text{C}$), 158.22, 147.14, 137.39, 133.16, 132.05, 128.35, 128.33, 127.64, 125.87, 115.84 ($2\times\text{CH}$), 112.42, 68.01, 61.55 ($5\times\text{CH}$), 53.40, 52.89, 43.60 ($5\times\text{CH}_2$), 42.48, 41.88, 41.80, 30.17, 30.00, 29.88, 29.68, 29.38, 26.29, 26.18, 25.90 ($4\times\text{CH}_2$), 24.33, 23.71, 20.88, 17.68, 14.47. HRMS (ESI⁺): calculated for $\text{C}_{57}\text{H}_{100}\text{N}_{24}\text{O}_9$ [$\text{M} + 2\text{H}$]²⁺ 633.4131, found 633.4116.

Evaluation methods of biological experiments

Antibacterial activity assay. The antibacterial activities of all the compounds were determined according to a broth dilution method specified in Clinical and Laboratory Standards Institute (CLSI) guidelines. Bacterial cells were inoculated on a Mueller-Hinton agar (MHA) plate for overnight culture, and the concentration of the bacterial cells was adjusted to about 1×10^6 colony-forming units (CFU)/mL with phosphate buffered saline (PBS). First, a 1000 $\mu\text{g/mL}$ stock solution (a final concentration of dimethyl sulfoxide (DMSO) was $\leq 2\%$) was prepared by dissolving a sample in

DMSO/H₂O. Then, the stock solution was diluted with Mueller-Hinton Broth (MHB) to an initial concentration of 100 µg/mL, and the sample solution (100 µL) was subjected to two-fold gradient dilution with MHB in a 96-well plate, to obtain 100 µg/mL to 0.78 µg/mL serial dilutions. Then, a bacterial suspension (100 µL) was added to each well of the 96-well plate and mixed with the test sample solution (100 µL). Among them, test systems for compounds **38**, **44-45**, **58-61** and **63-64** contained 0.05% of Tween 80. Finally, the 96-well plate was incubated at 37 °C for 24 hours. Absorbances at 600 nm at 0 and 24 h were measured. An minimum inhibitory concentration (MIC) value was defined as the lowest concentration where no visible bacterial growth occurred. All experiments were carried out in at least two duplicates, and biological repeatability could be achieved.

Hemolytic activity assay. Rabbit red blood cells were centrifuged at 2500 rpm for 3 minutes and then washed twice with PBS. Subsequently, a 8% (v/v) cell suspension was prepared by resuspending the rabbit red blood cells with PBS. A sample was first dissolved in DMSO or PBS (a final concentration of DMSO was $\leq 0.5\%$), and then diluted with PBS to prepare two-fold gradient dilutions (400 µg/mL to 3.125 µg/mL). The rabbit red blood cell suspension (100 µL) was mixed with the two-fold gradient dilutions (100 µL) of the sample. Then, the mixture was added to a sterile 96-well plate, incubated at 37 °C for 1 hour, and then centrifuged at 2500 rpm for 5 minutes. Among them, test systems for compounds **38**, **44-45**, **58-61** and **63-64** contained 0.05% of Tween 80. The supernatant (100 µL) was transferred to a new 96-well plate. Absorbance at 576 nm was measured using a Biotek multifunctional microplate reader. The positive control group was treated with a 2% Triton X-100 solution, and the negative control group was treated with PBS or 0.5% DMSO. The hemolytic activity was calculated by the following equation: % hemolytic activity = $[(\text{Abs}_{\text{sample}} - \text{Abs}_{\text{negative control}}) / (\text{Abs}_{\text{positive control}} - \text{Abs}_{\text{negative control}})] \times 100$. All experiments were carried out in at least two duplicates, and biological repeatability could be achieved.

Assay of toxicity to mammalian cells. The cytotoxicities of a compound to be tested to mouse fibroblasts NCTC clone 929, mouse corneal cells CM120 and human hepatocellular carcinoma cells Hep-G2 were evaluated by a CCK-8 method. Cells were inoculated to a 96-well plate according to the cell amount described in a CCK-8 kit (Beyotime, PRC) specification, and cultured at 37 °C with 5% CO₂ for 24 h. Then, a specific concentration of the sample to be tested was added to each well. Inoculation was further performed at 37 °C in an incubator for 24 h. Finally, a CCK-8 solution having a final concentration of 10% was added to each well. Incubation was further performed in the incubator for 1.0 h before absorbance at 450 nm (OD₄₅₀) of the solution was measured by a

microplate reader. According to formula (2), the cytotoxicity of the sample to be tested could be obtained:

$$\% \text{ cytotoxicity} = \frac{A_{\text{sample}} - A_{\text{blank}}}{A_{\text{no sample}} - A_{\text{blank}}} \times 100 \quad (2)$$

A_{sample} : absorbance of a well with cells, a CCK8 solution and a sample solution to be tested;

A_{blank} : absorbance of a well with a culture medium and a CCK8 solution but without cells; and

$A_{\text{no sample}}$: absorbance of a well with cells and a CCK8 solution but without a sample solution to be tested.

Evaluation of development tendency of drug resistance. Initial MIC values of compound 60, norfloxacin and gatifloxacin against *S. aureus* ATCC29213 were obtained by the above MIC determination method. Bacterial cells in a 96-well plate with a concentration of $0.5 \times \text{MIC}$ were taken out to prepare a bacterial suspension (about 1×10^6 CFU/mL) for the next MIC value determination. After incubating the sample at 37 °C for 24 hours, the change in the MIC value of each compound was measured. This experiment was carried out consecutively for 15 days.

Evaluation of *in vivo* efficacy. The experiment for evaluating *in vivo* antibacterial efficacy of animals had been approved by the Laboratory Animal Center of South China Agricultural University and was carried out according to the policy of the Ministry of Health of the People's Republic of China. Female C57BL6 mice (6-8 weeks, with an average weight of 20 g) were used as a bacterial keratitis model. In order to establish an immunosuppressive mouse model, cyclophosphamide (100 mg/kg) was injected intraperitoneally to mice three times 5 days before infection. Bacterial cells (*S. aureus* ATCC 29213) inoculated onto a Mueller Hinton agar (MHA) plate were suspended with PBS, and the concentration of the bacterial cells was adjusted to about 5×10^7 CFU/mL for corneal infection in mice. First, the mice were anesthetized. Then, the cornea of the left eye of the mouse was scratched with a sterile needle, and 15 µL of bacterial suspension was dropped on the injured cornea. One day after infection, the mice were randomized into three groups (5 mice per group). Three compounds (0.5% **60**, 5% glucose solution and 5% vancomycin) were applied topically four times a day for consecutive three days, respectively. Finally, the mice were euthanized, and their corneas were collected. Viable bacteria were counted by an MHA plate counting method. the P value was calculated using SPSS 22.0 software and $P \leq 0.05$ was considered as being statistically significant.

CD-1 mice (6-8 weeks, with an average weight of 25 g) were used as an abdominal infection model. First, the mice were injected with *S. aureus* ATCC29213 ($\text{OD}_{600} \approx 1.0$) intraperitoneally,

and the mice were randomized into three groups (5 mice per group). After 1 hour of infection, one group was dosed with **58** (5 mg/kg) intravenously for treatment, once every 4 hours; and meanwhile, one group dosed with vancomycin (20 mg/kg, IP) was used as a positive control group, and the other group dosed with a 0.9% sodium chloride injection was used as a blank control group. After two days of treatment, the survival rate of the mice was investigated.

Experimental results

Results of *in vitro* antibacterial activities of the bakuchiol derivatives are shown in tables 1 and 2.

Among them, compounds **5**, **6**, **9**, **11-16**, **23-35**, **38**, **39**, **44**, **45**, **49**, **51-53** and **58-64** show excellent antibacterial activities against Gram-positive bacteria, with the minimum inhibitory concentration (MIC) being 0.39-3.125 µg/mL. Compounds **23**, **24**, **26-30**, **44**, **59** and **63** exhibit broad-spectrum antibacterial activities and also show excellent antibacterial activities against Gram-negative bacteria, with the MIC value being 1.56-3.125 µg/mL.

Table 1. *In vitro* antibacterial activities of bakuchiol derivatives **5-29** (µg/mL)

Compd	MIC (µg/mL)			
	<i>S. aureus</i> ATCC29213	<i>E. coli</i> ATCC25922	MRSA N315	MRSA NCTC10442
5	1.56	>50	1.56	3.125
6	3.125	>100	3.125	3.125
8	6.25	>100	6.25	6.25
9	3.125	>100	3.125	3.125
11	3.125	>100	1.56	1.56
12	12.5	>100	3.125	3.125
13	1.56	12.5	0.78	1.56
14	1.56	12.5	0.78	1.56
15	1.56	12.5	1.56	1.56
16	1.56	100	0.78	1.56
17	6.25	>100	1.56	3.125
18	50	>100	12.5	50
20	1.56	>100	1.56	1.56
21	1.56	>100	3.125	3.125
22	3.125	>100	1.56	1.56
23	1.56	3.125	0.78	3.125
24	1.56	1.56	0.78	1.56
25	0.78	50	0.78	1.56
26	1.56	3.125	1.56	3.125
27	1.56	1.56	0.78	1.56
28	1.56	3.125	1.56	1.56
29	0.78	3.125	0.78	0.78

30	0.78	3.125	0.78	0.78
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Table 2. *In vitro* antibacterial activities of bakuchiol derivatives **30-64** ($\mu\text{g/mL}$)

Compd	MIC ($\mu\text{g/mL}$)			
	<i>S. aureus</i> ATCC29213	<i>E. coli</i> ATCC25922	MRSA N315	MRSA NCTC10442
31	1.56	6.25	0.78	1.56
32	0.78	6.25	0.78	0.78
33	1.56	12.5	0.39	0.78
34	1.56	6.25	0.78	0.39
35	3.125	25	1.56	3.125
38	0.78	6.25	1.56	0.78
39	3.125	12.5	3.125	3.125
40	6.25	>100	6.25	6.25
44	0.78	3.125	0.78	1.56
45	0.39	6.25	0.78	1.56
47	6.25	12.5	6.25	6.25
49	1.56	12.5	3.125	1.56
50	6.25	12.5	6.25	6.25
51	1.56	6.25	1.56	3.125
52	1.56	25	0.78	0.78
53	0.78	6.25	0.78	0.78
55	12.5	>100	12.5	12.5
56	6.25	25	6.25	6.25
58	0.39	12.5	0.39	0.39
59	0.78	1.56	0.78	0.78
60	0.39	12.5	0.39	0.78
61	0.78	25	0.39	0.78
63	0.78	3.125	0.78	0.78
64	1.56	25	1.56	1.56

Research results of *in vitro* cytotoxicity and hemolytic activity

Active compounds **44** and **60** at 100 $\mu\text{g/mL}$ show no obvious cytotoxicity to mouse corneal cells, with the cell survival rate being still kept at more than 90%. Active compounds **58** and **60** at 100 $\mu\text{g/mL}$ show no obvious cytotoxicity to mouse fibroblasts NCTC clone 929, with the cell survival rate being still kept at $89.3 \pm 0.6\%$ and $93.7 \pm 0.7\%$, respectively.

The hemolytic toxicities of active compounds **45**, **53**, **58**, **60**, **61**, **64** and **63** are very low, with the HC50 values (the concentration of a compound necessary to lyse 50% rabbit red blood cells) being all more than 400 $\mu\text{g/mL}$. The hemolytic toxicity of active compound **28** is also relatively low, with the HC50 value being 112.9 ± 5.0 $\mu\text{g/mL}$. The above results show that these bakuchiol compounds have comparatively high safety.

Research results of drug resistance

Overcoming the generation of drug resistance of bacteria has become one of the most important indicators for evaluating new antibacterial compounds. As shown in FIG. 1, after 15 days of continuous passage, the MIC value of compound **60** does not change significantly. However, obvious drug resistance to norfloxacin is produced, and there is a 16-fold increase in the MIC value after 15 days of continuous passage. These results show that compound **60** can effectively overcome the generation of drug resistance of bacteria.

Evaluation results of *in vivo* antibacterial activity

Compounds **58** and **60** show excellent *in vitro* antibacterial activities against Gram-positive bacteria as well as very low hemolytic activities and cytotoxicities. In a mouse model of bacterial keratitis caused by *S. aureus* ATCC29213, as shown in FIG. 2, the topical use of 0.5% compound **60** and 5% vancomycin reduces the number of bacteria in the infected mouse cornea by 4.48 log ($P < 0.01$) and 4.16 log ($P < 0.01$), respectively. In a mouse model of bacterial peritonitis caused by *S. aureus* ATCC29213, after two days of treatment, all five mice in the negative control group die. However, all five mice in each of the compound **58** treatment group and the vancomycin positive control group survive, with the survival rate being 100%. Compounds **58** and **60** show excellent *in vivo* antibacterial efficacy, which is comparable to vancomycin. These results show that compounds **58** and **60** can cure the bacterial infection caused by *S. aureus*.

It can be seen that compound **60** shows an excellent antibacterial effect in the mouse model of corneal infection caused by *S. aureus* ATCC29213 (administrated topically); and **58** shows excellent pharmacokinetic characteristics in mice, and shows excellent antibacterial efficacy in the mouse model of abdominal infection (administrated subcutaneously, intraperitoneally and intravenously, respectively). Such bakuchiol derivatives based on new molecular entities and new antibacterial mechanisms can effectively fight against drug-resistant bacterial infections, providing a new solution to the current antibiotic resistance crisis.

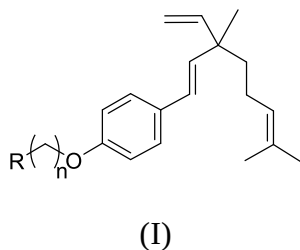
The technical features of the above embodiments may be arbitrarily combined. For brevity of description, all possible combinations of the technical features in the above embodiments are not described. However, as long as there is no contradiction between the combinations of these technical features, all these combinations should be considered as the scope of this specification.

The above embodiments are only used to express several implementations of the disclosure and are specifically described in details, but they cannot be understood therefore as limiting the patent scope of the disclosure. It should be pointed out that for those skilled in the art, without departing from the concept of the disclosure, a number of variations and improvements could be made, which

are all within the scope of protection of the disclosure. Therefore, the scope of patent protection of the disclosure shall be on the basis of the appended claims.

CLAIMS

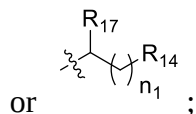
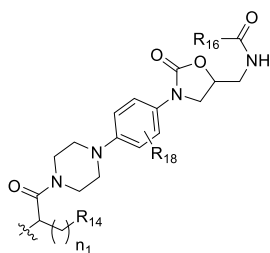
1. A bakuchiol derivative and a pharmaceutically acceptable salt thereof, the bakuchiol derivative having a structure shown in formula (I):



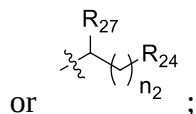
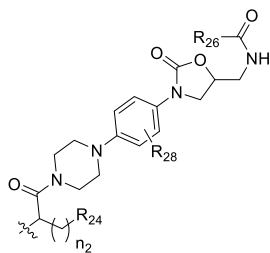
wherein n is an integer from 1 to 16;

R is selected from halo, $-\text{CONR}_1\text{R}_2$, $-\text{COOR}_3$, $-\text{NR}_4\text{R}_5$, $^+\text{N}(\text{R}_4)(\text{R}_5)\text{R}_6^- \text{Y}^-$, or $\text{H}_2\text{N}-\text{C}(\text{NH})=\text{N}-\text{H}$; ;

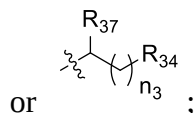
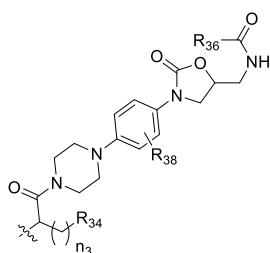
R_1 and R_2 are each independently selected from: $-\text{H}$,



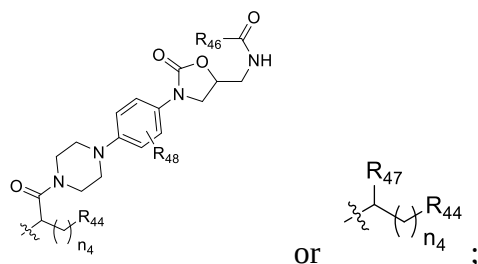
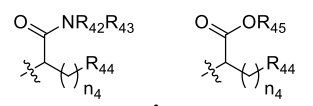
R_{12} and R_{13} are each independently selected from: $-\text{H}$,



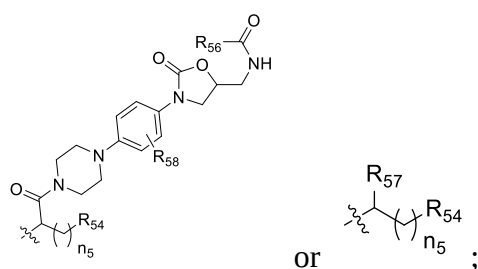
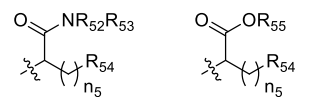
R_{22} and R_{23} are each independently selected from: $-\text{H}$,



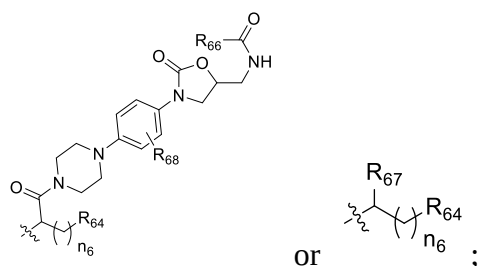
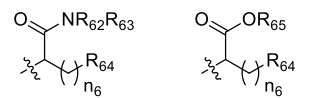
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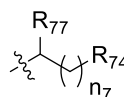
R₄₂ and R₄₃ are each independently selected from: -H,



R₅₂ and R₅₃ are each independently selected from: -H,

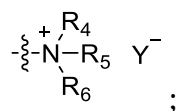
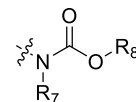


R₆₂ and R₆₃ are each independently selected from: -H or



wherein R₁₄, R₂₄, R₃₄, R₄₄, R₅₄, R₆₄ and R₇₄ are each independently selected from: -H,

guanidyl, -NR₄R₅, -SR₄, 5- to 20-membered nitrogen-containing heteroaryl,



or

R₁₅-R₁₇, R₂₅-R₂₇, R₃₅-R₃₇, R₄₅-R₄₇, R₅₅-R₅₇ and R₆₅-R₆₇ are each independently selected from:

-H or C₁₋₆ alkyl;

R₁₈, R₂₈, R₃₈, R₄₈, R₅₈ and R₆₈ are each independently selected from: -H, C₁₋₆ alkyl or halogen;

each of n₁, n₂, n₃, n₄, n₅, n₆ and n₇ is independently 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10;

R_{77} is selected from: -H or C_{1-6} alkyl;

R_3 is selected from: -H or C_{1-4} alkyl;

R_4 and R_5 are each independently selected from: -H, C_{1-16} alkyl, $COOR_8$, -Fmoc or R_a -substituted C_{1-16} alkyl; or R_4 and R_5 together with N linked thereto are capable of forming a 5- to 20-membered heterocyclic ring, a 5- to 20-membered heteroaromatic ring, a 5- to 20-membered heterocyclic ring substituted by R_b or a 5- to 20-membered heteroaromatic ring substituted by R_b ;

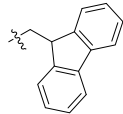
R_a is selected from: 5- to 10-membered aryl, 5- to 10-membered heteroaryl, $-NR_{a1}R_{a2}$ or $-SR_{a3}$;

R_b is selected from: C_{1-10} alkyl, $-(CH_2)_pNR_{b1}R_{b2}$ or $-SR_{b3}$, wherein p is 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10;

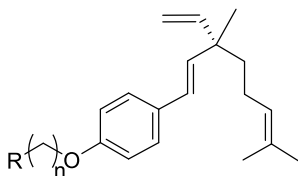
each of R_{a1} , R_{a2} , R_{b1} and R_{b2} is independently -H, C_{1-10} alkyl or R_c -substituted C_{1-10} alkyl; or R_{a1} and R_{a2} together with a N atom linked thereto are capable of forming a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring; or R_{b1} and R_{b2} together with a N atom linked thereto are capable of forming a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring;

each of R_{a3} and R_{b3} is independently C_{1-10} alkyl;

R_c is selected from: $-NR_{c1}R_{c2}$, guanidyl or 5- to 6-membered nitrogen-containing heteroaryl, wherein each of R_{c1} and R_{c2} is independently: -H, C_{1-4} alkyl; or R_{c1} and R_{c2} together with a N atom linked thereto are capable of forming a 5- to 10-membered heterocyclic ring or a 5- to 10-membered heteroaromatic ring;

R_6 is C_{1-4} alkyl; R_7 is selected from: -H or C_{1-4} alkyl; R_8 is -H, C_{1-6} alkyl or ; and Y- is an anion.

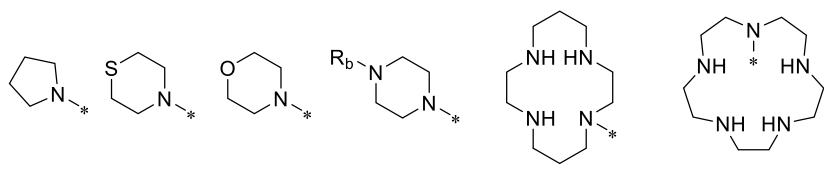
2. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 1, having a structure shown in formula (I'):



(I').

3. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to

claim 1, wherein R_4 and R_5 are each independently selected from: H, C_{1-12} alkyl, $COOR_8$, -Fmoc or R_a -substituted C_{1-10} alkyl; or R_4 and R_5 together with N linked thereto are capable of forming the following heterocyclic rings:



wherein R_a is selected from pyridine, pyrimidine, triazine, $-NR_{a1}R_{a2}$ or $-SR_{a3}$;

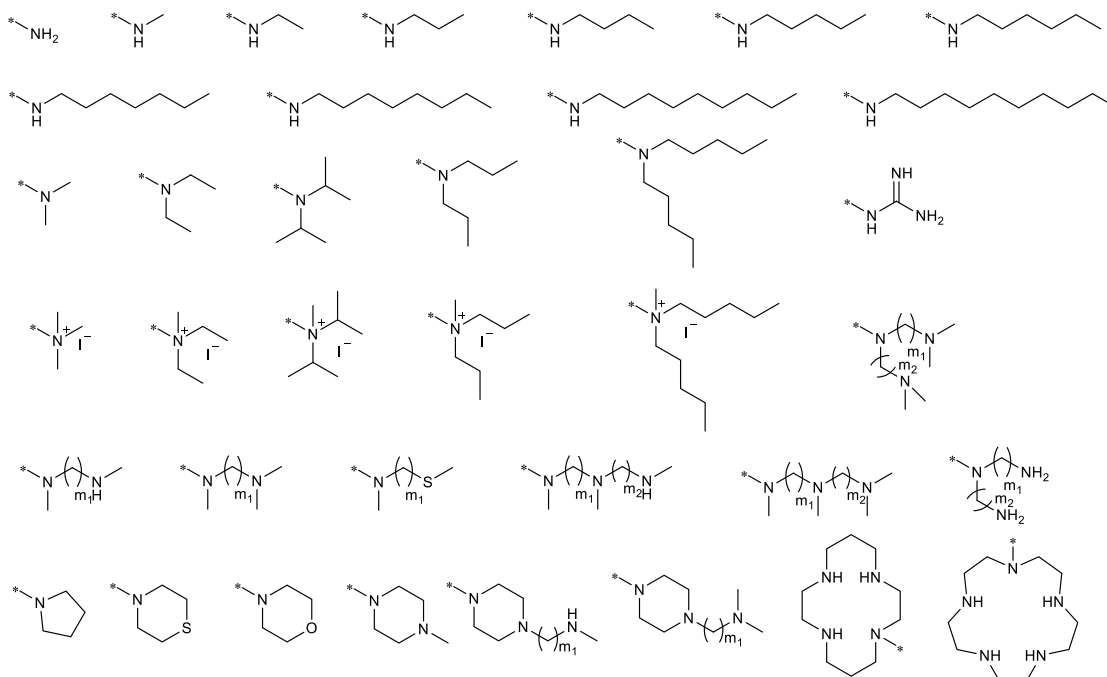
each of R_{a1} and R_{a2} is independently H, C_{1-4} alkyl or $NR_{c1}R_{c2}$ -substituted C_{1-4} alkyl; R_{a3} is C_{1-4} alkyl;

each of R_{c1} and R_{c2} is independently H or C_{1-4} alkyl;

R_b is selected from H, C_{1-6} alkyl or $-(CH_2)_pNR_{b1}R_{b2}$, wherein p is 0, 1, 2, 3, 4, 5 or 6; and

each of R_{b1} and R_{b2} is independently H or C_{1-4} alkyl.

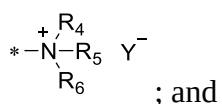
4. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 1, wherein R is selected from the following groups:



wherein each of m_1 and m_2 is independently 1, 2, 3, 4, 5, 6, 7 or 8.

5. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 1, wherein R_{14} , R_{24} , R_{34} , R_{44} , R_{54} , R_{64} and R_{74} are each independently selected from: -H,

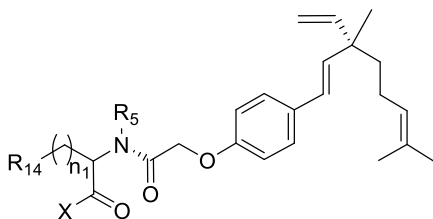
guanidyl, $-NR_4R_5$, $-SR_4$, 5-membered nitrogen-containing heteroaryl, $^*NHC(=O)OR_8$ or



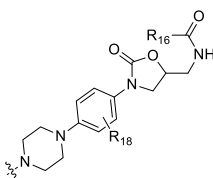
; and

R₈ is C₁₋₄ alkyl.

6. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 1, selected from a compound of the following general formula:



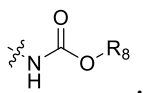
(II'),



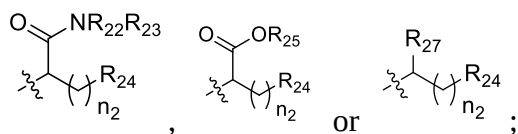
wherein X is NR₁₂R₁₃, OR₁₅ or .

7. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to

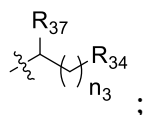
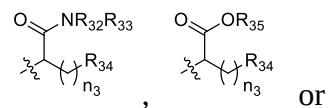
claim 6, wherein X is OR₁₅, and R₁₄ is selected from: H, guanidyl, -NH₂, -SCH₃,  or



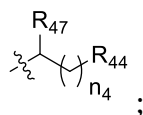
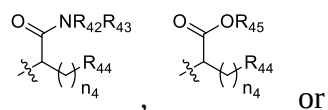
8. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 6, wherein X is NR₁₂R₁₃; one of R₁₂ and R₁₃ is H, and another one is selected from



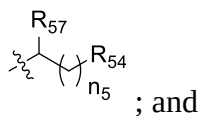
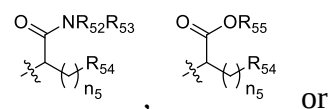
one of R₂₂ and R₂₃ is H, and another one is selected from



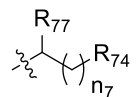
one of R₃₂ and R₃₃ is H, and another one is selected from



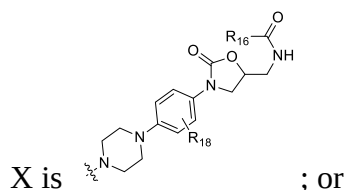
one of R_{42} and R_{43} is H, and another one is selected from



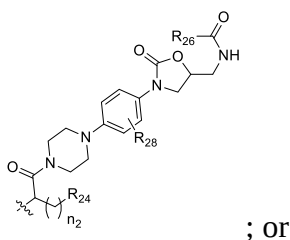
one of R_{62} and R_{63} is H, and another one is selected from



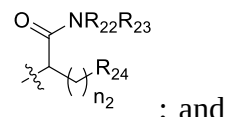
9. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 6, wherein



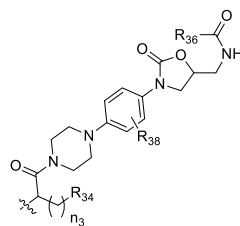
X is $\text{NR}_{12}\text{R}_{13}$; and one of R_{12} and R_{13} is H, and another one is selected from



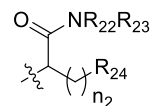
X is $\text{NR}_{12}\text{R}_{13}$; one of R_{12} and R_{13} is H, and another one is selected from



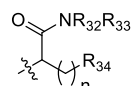
one of R_{22} and R_{23} is H, and another one is selected from



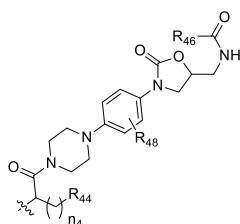
X is $\text{NR}_{12}\text{R}_{13}$; one of R_{12} and R_{13} is H, and another one is selected from



R_{22} and R_{23} is H, and another one is selected from

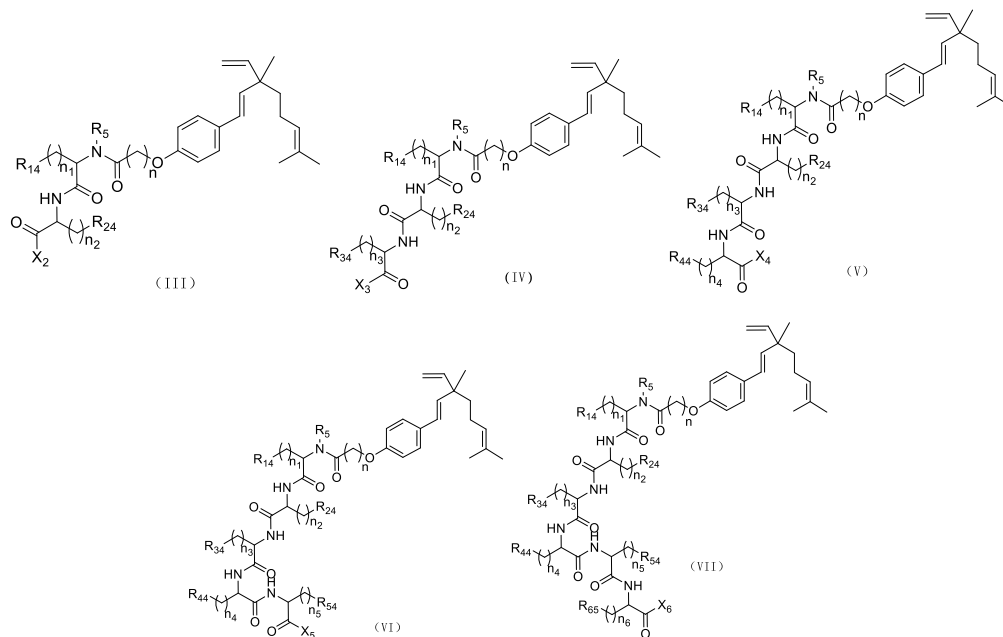


another one is selected from

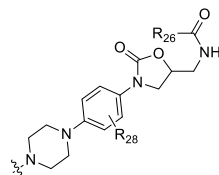


10. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to

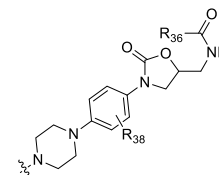
claim 1, selected from a compound of any of the following general formulae:



wherein X_2 is $NR_{22}R_{23}$, OR_{25} or

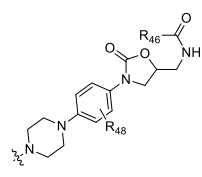


; X_3 is $NR_{32}R_{33}$, OR_{35} or

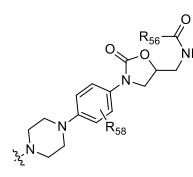


;

X_4 is $NR_{42}R_{43}$, OR_{45} or

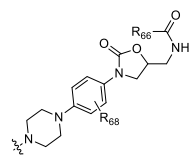


; X_5 is $NR_{52}R_{53}$, OR_{55} or



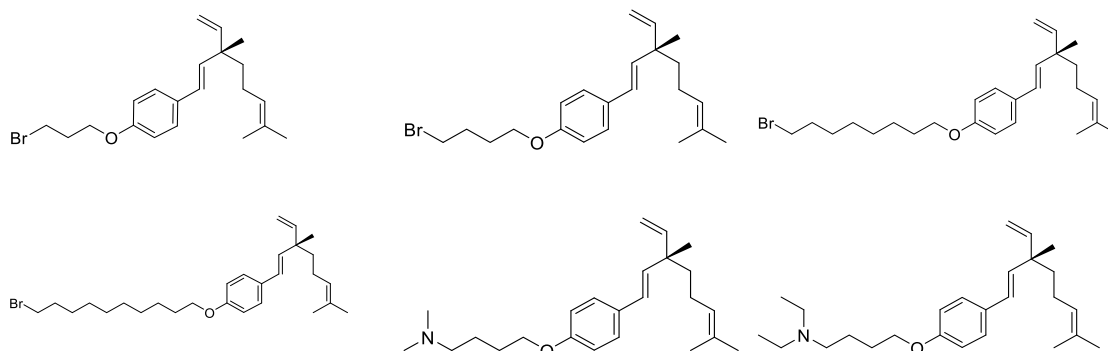
; and X_6 is

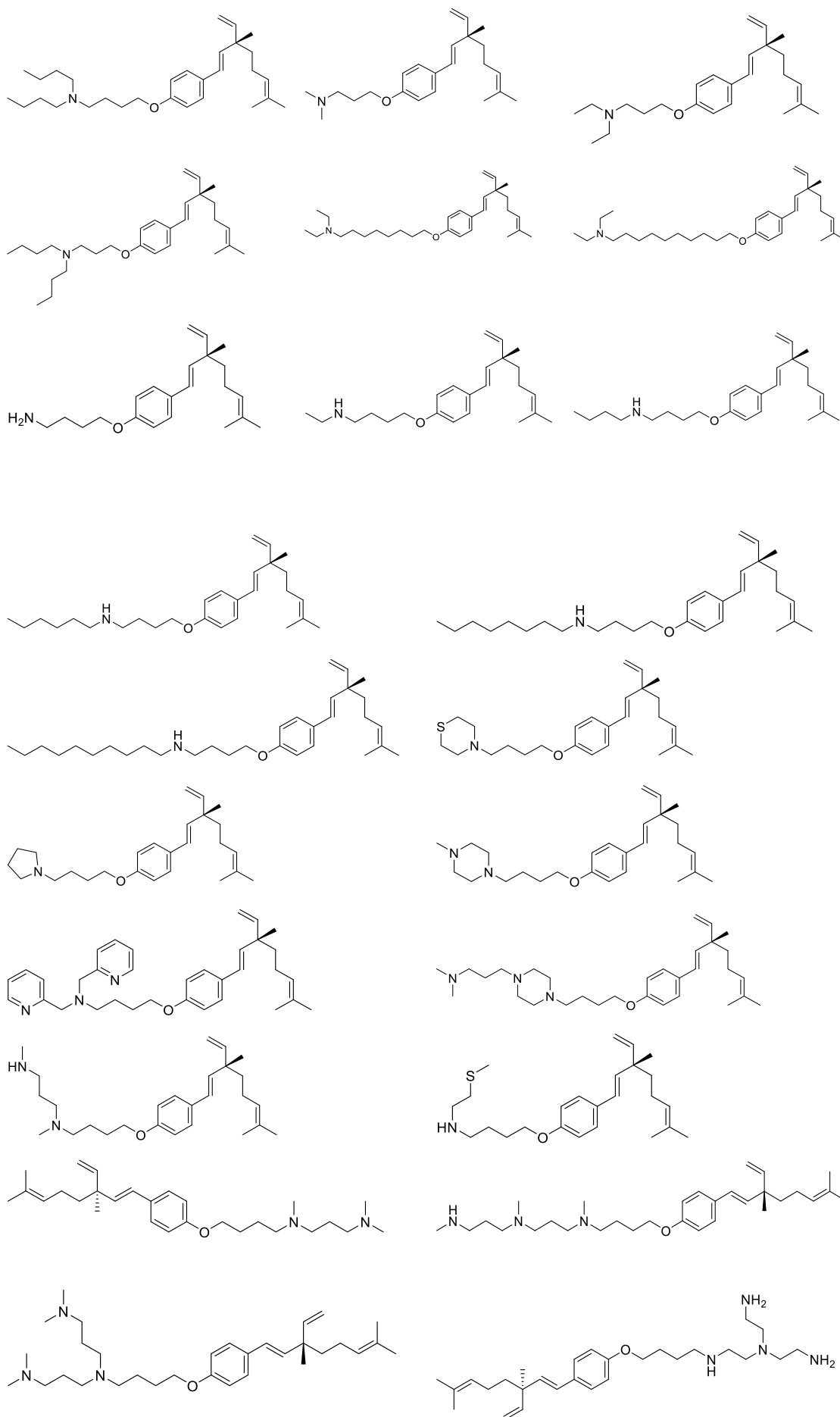
$NR_{62}R_{63}$, OR_{65} or

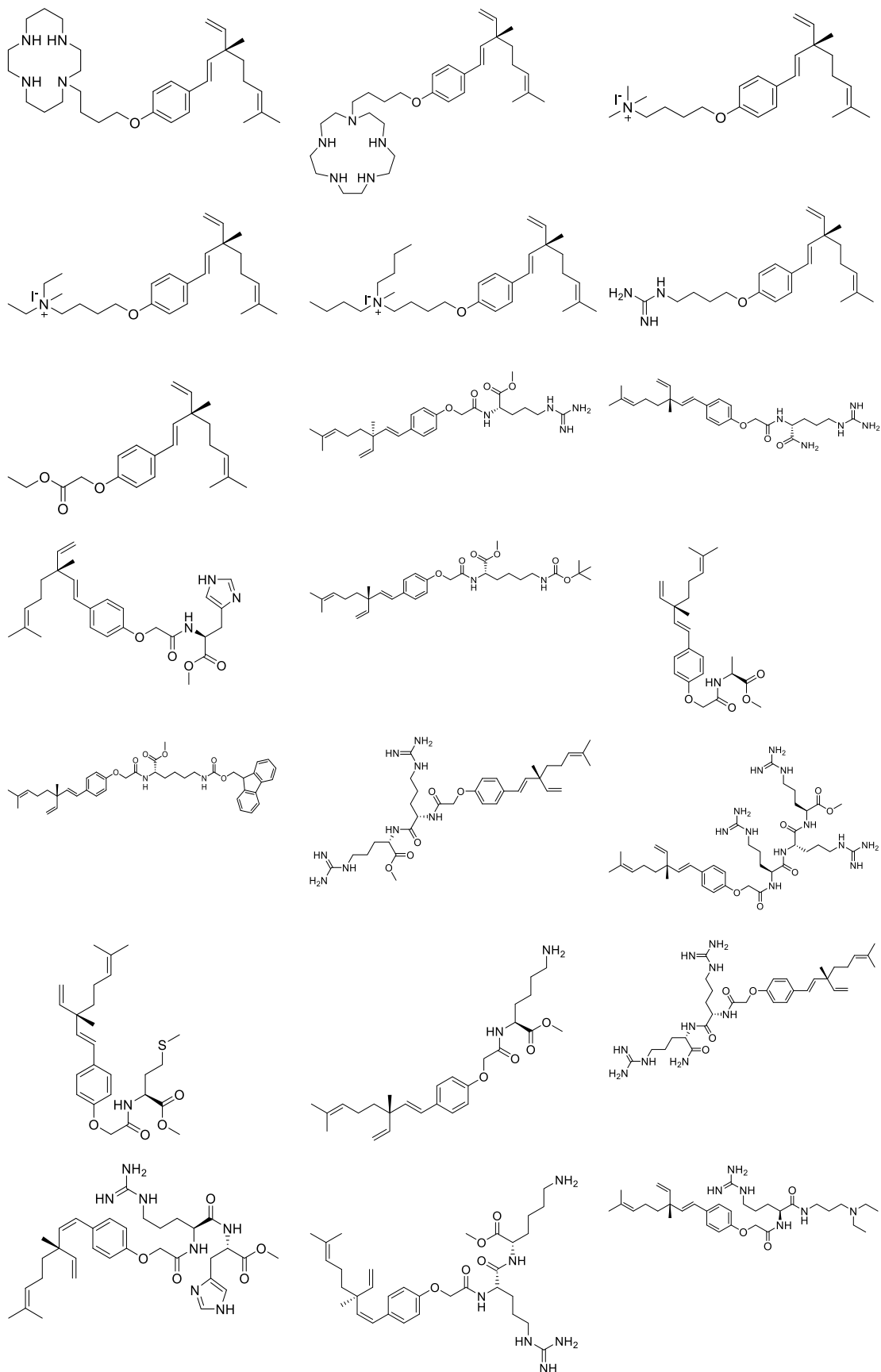


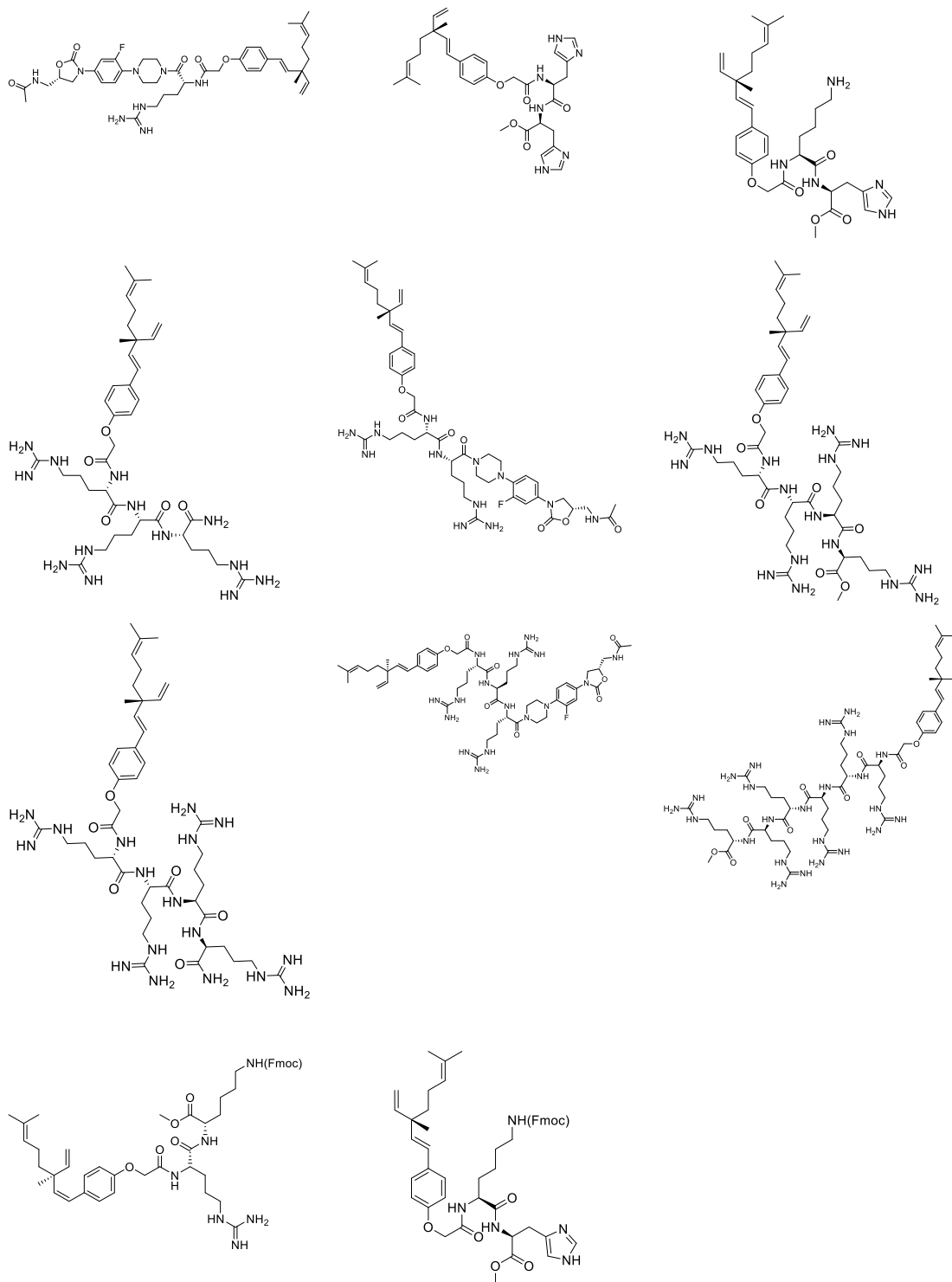
.

11. The bakuchiol derivative and a pharmaceutically acceptable salt thereof according to claim 1, selected from the following compounds:

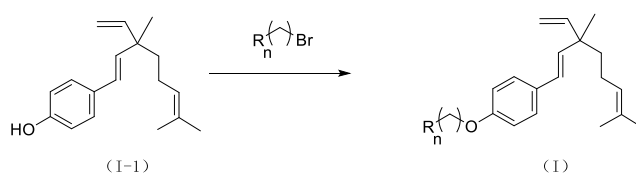








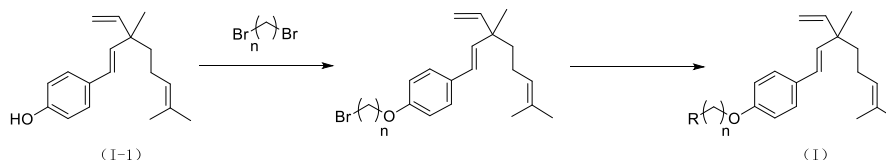
12. A preparation method of the bakuchiol derivative and a pharmaceutically acceptable salt thereof of any one of claims 1-11, wherein when R is a halogen, the preparation method comprises the following step:



reacting a compound shown in formula (I-1) with $R_n(\text{CH}_2)_n\text{Br}$, to obtain a compound shown in

formula (I-1) with R being a halogen;

when R is NR_4R_5 , $\begin{array}{c} \text{R}_4 \\ | \\ \text{---N}^+-\text{R}_5 \\ | \\ \text{R}_6 \end{array} \text{Y}^-$ or $\begin{array}{c} \text{H} \\ | \\ \text{H}_2\text{N}-\text{C}=\text{N}- \\ | \\ \text{NH} \end{array}$, the preparation method comprises the following steps:

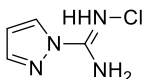


reacting a compound shown in formula (I-1) with $\text{Br}-(\text{CH}_2)_n-\text{Br}$, to obtain an intermediate with R being Br;

reacting the intermediate with R being Br with HNR_4R_5 , to obtain a compound shown in formula (I) with R being NR_4R_5 ;

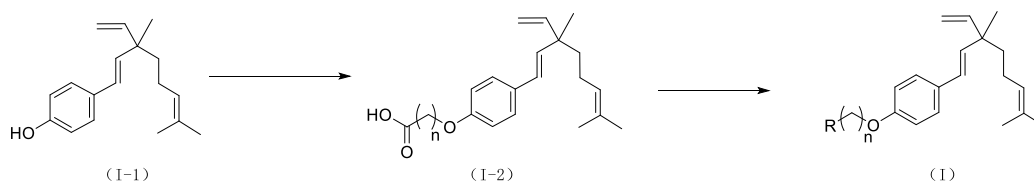
reacting the compound shown in formula (I) with R being NR_4R_5 with haloalkyl, to obtain a

compound shown in formula (I) with R being $\begin{array}{c} \text{R}_4 \\ | \\ \text{---N}^+-\text{R}_5 \\ | \\ \text{R}_6 \end{array} \text{Y}^-$; and

reacting a compound shown in formula (I) with R being NH_2 with , to obtain a

compound shown in formula (I) with R being $\begin{array}{c} \text{H} \\ | \\ \text{H}_2\text{N}-\text{C}=\text{N}- \\ | \\ \text{NH} \end{array}$; and

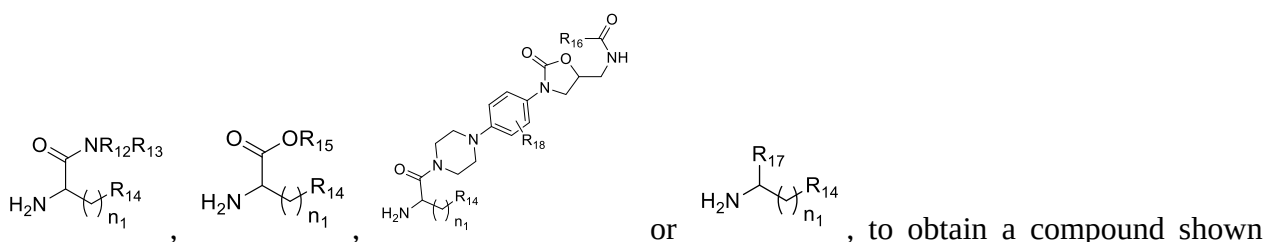
when R is selected from CONR_1R_2 and $-\text{COOR}_3$, the preparation method comprises the following steps:



performing a condensation reaction on a compound shown in formula (I-1) and an alkyl bromoalkylate, to obtain a compound shown in formula (I) with R being $-\text{COOR}_3$;

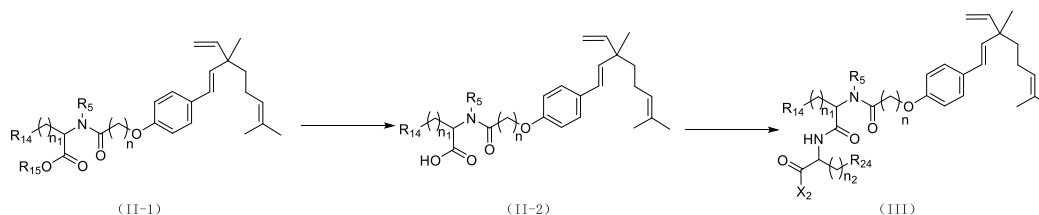
hydrolyzing to obtain a compound shown in formula (I-2); and

performing a condensation reaction on the compound shown in formula (I-2) and



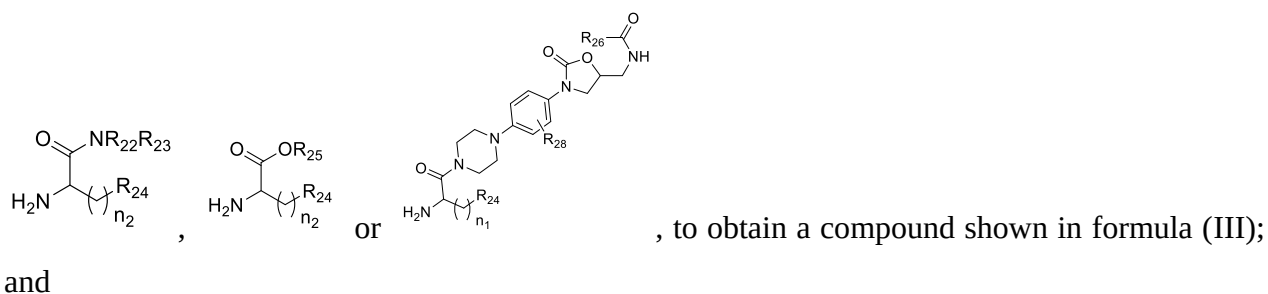
in formula (I) with R being CONR_1R_2 .

13. The preparation method according to claim 12, wherein when R is selected from CONR_1R_2 , the preparation method further comprises the following steps:



performing a hydrolysis reaction on a compound shown in formula (II-1), to obtain a compound shown in formula (II-2);

performing a condensation reaction on the compound shown in formula (II-2) and



optionally, according to this cycle, hydrolyzing a compound containing an ester group, and then performing a condensation reaction with corresponding amine, to obtain a compound shown in formula (I) containing a target fragment;

wherein X_2 is as defined in claim 10.

14. A pharmaceutical composition comprising at least one of the bakuchiol derivative and a pharmaceutically acceptable salt thereof of any one of claims 1-11, and a pharmaceutically acceptable excipient.

15. Use of the bakuchiol derivative and a pharmaceutically acceptable salt thereof of any one of claims 1-11 or the pharmaceutical composition of claim 14 in preparation of antibacterial agents.