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(54) Titre : METHODE D'UTILISATION DE DICETOPIPERAZINES ET COMPOSITION CONTENANT CES SUBSTANCES
(54) Title: METHOD OF USING DIKETOPIPERAZINES AND COMPOSITION CONTAINING THEM

(57) Abrégé/Abstract:
The invention provides a method of inhibiting the effects of platelet activating factor (PAF). For instance, a disease or condition mediated by PAF (particularly inflammation) can be treated or platelet aggregation can be inhibited. The invention also provides a method of inhibiting the production and/or release of interleukin 8 (IL-8) by cells. The effects of PAF and the production and/or release of IL-8 are inhibited according to the invention by a compound of formula (1) wherein R^1 and R^2 are defined in the application, or a physiologically-acceptable salt thereof. The invention also provides pharmaceutical compositions comprising these compounds.

ABSTRACT

The invention provides a method of inhibiting the effects of platelet activating factor (PAF). For instance, a disease or condition mediated by PAF (particularly inflammation) can be treated or platelet aggregation can be inhibited. The invention also provides a method of inhibiting the production and/or release of interleukin 8 (IL-8) by cells. The effects of PAF and the production and/or release of IL-8 are inhibited according to the invention by a compound of formula (1) wherein R^1 and R^2 are defined in the application, or a physiologically-acceptable salt thereof. The invention also provides pharmaceutical compositions comprising these compounds.

METHOD OF USING DIKETOPIPERAZINES AND COMPOSITION CONTAINING THEM

FIELD OF THE INVENTION

This invention relates to methods of inhibiting the effects of platelet activating factor using certain diketopiperazines. The invention also relates to methods of inhibiting the production and/or release of interleukin 8 (IL-8) using these diketopiperazines. Finally, the invention relates to pharmaceutical compositions comprising the diketopiperazines.

BACKGROUND

Platelet activating factor (PAF; 1-O-alkyl-2-acetyl-*sn*-glycerol-3-phosphorylcholine) is a potent inflammatory phospholipid mediator with a wide variety of biological activities. It is generated and released by basophils, monocytes, macrophages, polymorphonuclear leukocytes, eosinophils, neutrophils, natural killer lymphocytes, platelets and endothelial cells, as well as by renal and cardiac tissues under appropriate immunological and non-immunological stimulation. See PCT application WO 94/04537. PAF mediates biological responses by binding to specific PAF receptors found in a wide variety of cells and tissues. Structure-activity studies on PAF and its analogs indicate that the ability of PAF to bind to these receptors is structure specific and stereospecific. See PCT WO 94/04537.

While PAF mediates essential biological responses, it also appears to play a role in pathological immune and inflammatory responses. Many published studies have provided evidence for the involvement of PAF in diseases, including arthritis, acute inflammation, asthma, allergic reactions, cardiovascular diseases, neoplastic diseases, endotoxic shock, pain, psoriasis, ophthalmic inflammation, ischemia, gastrointestinal ulceration, myocardial infarction, inflammatory bowel diseases, and acute respiratory distress syndrome. See PCT application WO 94/04537.

The involvement of PAF in pathological inflammatory and immune states has stimulated a substantial research effort to identify PAF receptor antagonists, and a number of compounds of diverse chemical structure have been identified as PAF antagonists. See, *e.g.*, PCT applications WO 94/04537 and WO 96/00212 (and references cited in these two applications), PCT applications WO 95/18610 and WO 99/49865, U.S. Patents Nos. 4,940,709, 5,358,938, 5,434,151, 5,463,083, 5,648,486, 5,741,8095,792,776, 5,780,503, 5,856,323, Japanese application 63 290868, Shimazaki et al., *Chem. Pharm. Bull.*, **35(8)**, 3527-3530 (1987), Shimazaki et al., *J. Med. Chem.*, **30**, 1709-1711 (1987), Yoshida et al.,

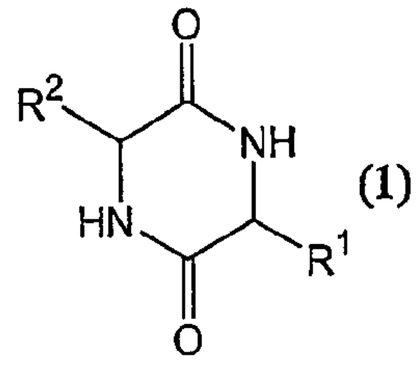
Prog. Biochem. Pharmacol., **22**, 68-80 (1988), Shimazaki et al., *Lipids*, **26(12)**, 1175-1178 (1991). Given the significant number of pathological immune and inflammatory responses that are mediated by PAF, there remains a need to identify new compounds and compositions that inhibit PAF activity.

Diketopiperazines have been reported to exhibit a variety of biological activities. See, *e.g.*, U.S. Patents Nos. 4,289,759 (immunoregulatory agents), 4,331,595 (immunoregulatory agents), 4,940,709 (PAF antagonists), 5,700,804 (inhibitors of plasminogen activator inhibitor), 5,750,530 (inhibitors of plasminogen activator inhibitor), 5,990,112 (inhibitors of metalloproteases), PCT applications WO 97/36888 (inhibitors of farnesyl-protein transferase) and WO 99/40931 (treatment of central nervous system injury), EP application 43219 (immunoregulatory agents), Japanese application 63 290868 (PAF antagonists), Japanese application 31 76478 (immunosuppressive agents), Shimazaki et al., *Chem. Pharm. Bull.*, **35(8)**, 3527-3530 (1987) (PAF antagonists), Shimazaki et al., *J. Med. Chem.*, **30**, 1709-1711 (1987) (PAF antagonists), Shimazaki et al., *Lipids*, **26(12)**, 1175-1178 (1991) (PAF antagonists), Yoshida et al., *Prog. Biochem. Pharmacol.*, **22**, 68-80 (1988) (PAF antagonists), Alvarez et al., *J. Antibiotics*, **47(11)**, 1195-1201 (1994) (inhibitors of calpain)

The diketopiperazine composed of aspartic acid and alanine (3-methyl-2,5-diketopiperazine-6-acetic acid; DA-DKP) is known. It has been reported to be formed as a result of the degradation of human albumin stored above 30°C. Chan et al., *Eur. J. Biochem.*, **227**, 524-528 (1995). It is not known to have biological activity.

SUMMARY OF THE INVENTION

The invention provides a method of treating a disease or condition mediated by platelet activating factor. The method comprises administering to an animal in need thereof an effective amount of a diketopiperazine of the formula:



(1)

wherein:

R^1 is $-CH_2COR^3$, or $-CH_2CH_2COR^3$;

R^2 is the side chain of an amino acid selected from the group consisting of glycine, alanine, valine, leucine, isoleucine, serine, threonine, aspartic acid, asparagine, glutamic acid, glutamine, lysine, hydroxylysine, histidine, arginine, phenylalanine, tyrosine, tryptophan, thyroxine, cysteine, methionine, norvaline and ornithine;

R^3 is $-OH$, $-NH_2$, $-OR^4$, $-NHR^4$, or $-NR^4R^4$; and

each R^4 is independently an alkyl, aryl, alkylaryl, or arylalkyl; or

a physiologically-acceptable salt thereof.

The invention further provides a method of inhibiting inflammation. The method comprises administering to an animal in need thereof an effective amount of a compound of formula **(1)** or a physiologically-acceptable salt thereof.

The invention also provides a method of inhibiting aggregation of platelets. The method comprises contacting the platelets with an effective amount of a compound of formula **(1)** or a physiologically-acceptable salt thereof.

In addition, the invention provides a method of inhibiting the production, release or both of interleukin 8 by cells. The method comprises contacting the cells with an effective amount of a compound of formula **(1)** or a physiologically-acceptable salt thereof.

The invention further provides a method of inhibiting the effects of platelet activating factor (PAF). The method comprises contacting the PAF with an effective amount of a compound of formula **(1)** or a physiologically-acceptable salt thereof.

Finally, the invention provides a pharmaceutical composition. The composition comprises a pharmaceutically-acceptable carrier and a compound of formula **(1)** or a physiologically-acceptable salt thereof.

DETAILED DESCRIPTION OF THE PRESENTLY-PREFERRED EMBODIMENTS

By "side chain" of an amino acid is meant that portion of the amino acid attached to the common NH_2-$\underset{|}{C}$H-COOH backbone of all of the amino acids listed above. For instance, the side chain of glycine is -H, the side chain of alanine is $-CH_3$, and the side chain of serine is $-CH_2OH$.

By "alkyl" is meant a straight-chain or branched-chain alkyl containing 1-30 carbon atoms, preferably 1-18 carbon atoms. "Lower alkyl" means a straight-chain or branched chain alkyl containing 1-6 carbon atoms.

By "aryl" is meant an aromatic group having at least one aromatic ring (*e.g.*, phenyl).

By "alkylaryl" is meant a lower alkyl having an aryl having attached thereto (*e.g.*, $-CH_2C_6H_5$ or $-CH_3CH(C_6H_5)CH_3$).

By "arylalkyl" is meant an aryl having a lower alkyl having attached thereto (*e.g.*, $-C_6H_4-CH_3$).

"Inhibit" is used herein to mean to reduce (wholly or partially) or to prevent.

"Mediated" is used herein to mean caused by, exacerbated by, or involving.

"Treat" is used herein to mean to reduce (wholly or partially) the symptoms of a disease or condition, including curing the disease or condition, or to prevent the disease or condition.

The present invention is based on the discovery that 3-methyl-2,5-diketopiperazine-6-acetic acid (DA-DKP) inhibits PAF activity. This inhibition appears to be due to the binding of DA-DKP to both PAF and PAF receptors. It is believed that the binding of DA-DKP to PAF is due to ion pairing of the carboxyl of DA-DKP with N^+ on the choline portion of PAF. Thus, other diketopiperazines comprising one or more carboxyls would be expected to be effective inhibitors of PAF. Indeed, it is possible that other non-diketopiperazine compounds comprising carboxyls, such as poly-aspartic acid or poly-glutamic acid, would also be effective inhibitors of PAF. The mechanism by which DA-DKP binds to PAF receptors is not known, but it is hypothesized to be due to the diketopiperazine ring structure of the DA-DKP and/or the hydrophobic R^2 side chain of DA-DKP.

Methods of preparing diketopiperazines are known in the art, and these methods may possibly be employed to synthesize the diketopiperazines of formula **(1)**. See, *e.g.*, U.S. Patents Nos. 4,694,081 and 5,817,751; Smith et al., *Bioorg. Med. Chem. Letters*, **8**, 2369-2374 (1998). However, difficulties may be encountered or unsatisfactory results may be obtained when using prior art methods to synthesize diketopiperazines of formula **(1)** (see co-pending provisional application 60/223,075, filed on August 4, 2000). Accordingly, it is highly preferable that the diketopiperazines of formula **(1)** be synthesized as described in co-

pending provisional application 60/223,075.

The synthesis described in provisional application 60/223,075 utilizes standard solution-phase or solid-phase peptide synthetic methods which are well known in the art. Solid-phase peptide synthetic methods are preferred.

The first step of the synthesis described in provisional application 60/223,075 comprises providing a first amino acid. The first amino acid is selected from the group consisting of glycine, alanine, valine, leucine, isoleucine, serine, threonine, aspartic acid, asparagine, glutamic acid, glutamine, lysine, hydroxylysine, histidine, arginine, phenylalanine, tyrosine, tryptophan, thyroxine, cysteine, methionine, norvaline and ornithine. These amino acids, which may be in their D- or L-enantiomeric form, are commercially available or can be made by methods well known in the art (see, *e.g.*, Williams, *Synthesis Of Optically Active a-Amino Acids* (Pergammon Press, 1989)). Preferred are hydrophobic amino acids such as glycine, alanine, valine, leucine, isoleucine, and phenylalanine. Particularly preferred is alanine.

The first amino acid is also preferably protected with one or more protecting groups to prevent unwanted side reactions during the synthesis. Such protecting groups, and methods for attaching and removing them, are well known in the art. See, *e.g.*, Green and Wuts, *Protective Groups In Organic Chemistry* (Wiley 1992) and Grant, *Synthetic Peptides: A User's Guide* (Freemen 1992).

The first amino acid is reacted with an aspartic acid derivative of the following formula $NH_2CH(CH_2COOR^5)COOH$ or a glutamic acid derivative of the following formula $NH_2CH(CH_2CH_2COOR^5)COOH$, wherein R^5 is a lower alkyl or alkylaryl. Preferably R^5 is benzyl ($-CH_2C_6H_5$;Bz). The benzyl group has been found not only to protect the side-chain carboxyls of these amino acids, but also to facilitate cyclization of the dipeptide. Furthermore, the benzyl can be removed from the dipeptide under neutral conditions which prevents racemization of the chiral center (carbons bearing the R^1 and R^2 groups).

The aspartic and glutamic acid derivatives $NH_2CH(CH_2COOR^5)COOH$ and $NH_2CH(CH_2CH_2COOR^5)COOH$ are commercially available or may be prepared by known methods (see, *e.g.*, Bodansky and Bodansky, *The Practice of Peptide Synthesis*, pages 63-66 (2nd ed., Springer-Verlag, 1994). The amino group or a carboxyl group of the aspartic and

glutamic acid derivatives can optionally be blocked with a standard protecting group (see above) in order to prevent unwanted side reactions.

As noted above, the synthesis of the diketopiperazines preferably utilizes solid-phase peptide synthetic methods. The first amino acid or the aspartic or glutamic acid derivative is attached to a solid support through its α carboxyl for solid-phase synthesis. The solid support may be any solid support which is compatible with peptide synthesis, such as those described in Grant and Atherton, S*olid Phase Peptide Synthesis: A Practical Approach* (IRL Press 1989). Suitable solid supports are available commercially or can be prepared by standard methods. See PCT application WO 96/00391. The solid support may contain linker or spacer molecules which anchor the first amino acid or the aspartic acid or glutamic acid derivative to the support surface. A variety of linkers with different properties are well known in the art. See, *e.g.*, Grant, *Synthetic Peptides: A User's Guide* (Freemen 1992) and PCT application WO 96/00391. The linker will typically include a functional group to which the first amino acid or the aspartic acid or glutamic acid derivative is attached.

Preferably, the first amino acid is attached to the solid support and, prior to coupling the aspartic acid or glutamic acid derivative to the first amino acid, the protecting group, if present, on the α amino group of the bound first amino acid is removed. The removal of the protecting group of any side-chain amino groups should be avoided, however, so conditions must be chosen to deprotect the α amino group without deprotecting the side chain amino groups. Suitable deprotection conditions are known in the art. For example, removal of 9-fluorenylmethyloxycarbonyl may be performed with 20% to 55% of a secondary amine base, such as piperidine, in a polar, aprotic solvent, such as dimethylformamide, methylene chloride or N-methylpyrrolidine. Diisopropyl silane is preferably added to prevent transesterification during deprotection, which can be pronounced in large scale preparations.

The reaction between the first amino acid and the aspartic or glutamic acid derivative takes place under conditions effective to produce a peptide bond so that a dipeptide is formed. These conditions are well known in the art. For instance, a coupling catalyst (such as 2-(1H-benzotriazole-1-yl)-1,2,3,3-tetramethyluroniumtetrafluoroborate, benzotriazole-1-yl-oxytris(dimethylamino)phosphonium hexafluorophospate, 2-(1H-benzotriazole-1-yl)-1,1,3,3-tetramethyluroniumhexaphosphate, 1-hydroxybenzotriazole, diisopropylamine, dicyclohexylcarbodiimide,) may be used to effect formation of the dipeptide. Typically, an

excess of the coupling catalyst is used, with quantities ranging from 2 to 10 equivalents or more. Often the degree of excess is determined with respect to the reactivity of the chemical species being coupled. Polar, aprotic solvents (such as dimethylformamide, N-methylpyrollidine, methylene chloride and dimethylsulfoxide) are preferred. Reaction times may vary from one-half hour to overnight, and temperatures may vary from room temperature to reflux.

Next, if the dipeptide is bound to a solid support, it is removed from the solid support using standard procedures well known in the art. The conditions effective to remove the dipeptide from the solid support will be depend on the solid support and linker chosen. Generally, the peptide will be removed by acid hydrolysis using a strong acid, such as trifluoroacetic acid.

The dipeptide is then cyclized to form a diketopiperazine; this diketopiperazine will have the side-chain carboxyl of the aspartic acid or glutamic acid derivative still in the ester form. Cyclization is accomplished by heating the dipeptide under neutral conditions. Typically, the dipeptide will be heated at from about 80°C to about 180°C, preferably at about 120°C. The solvent will be a neutral solvent. For instance, the solvent may comprise an alcohol (such as butanol, methanol, ethanol, and higher alcohols, but not phenol) and an azeotropic co-solvent (such as toluene, benzene, or xylene). Preferably, the alcohol is butan-2-ol, and the azeotropic co-solvent is toluene. The heating is continued until the reaction is complete, and such times can be determined empirically. Typically, the dipeptide will be cyclized by refluxing it for about 8-24 hours, preferably about 18 hours.

Finally, the R^5 group is removed from the diketopiperazine by methods well known in the art for removing protecting groups (see above). When the R^5 group is benzyl, it is preferably removed from the diketopiperazine by hydrogenation using a palladium on carbon (Pd/C) catalyst. The use of strong acids (mineral acids, such as sulfuric or hydrochloric acids), strong bases (alkaline bases, such as potassium hydroxide or sodium hydroxide), and strong reducing agents (*e.g.*, lithium aluminum hydride) should be avoided, in order to maintain the chirality of the final compound.

Once the R^5 group has been removed, the free acid can be derivatized, if desired, to form standard derivatives, such as amides and esters. Methods which can be used to convert the free acid to an amide or ester are well known in the art.

The physiologically-acceptable salts of the diketopiperzines of formula **(1)** may also be used in the practice of the invention. Physiologically-acceptable salts include conventional non-toxic salts, such as salts derived from inorganic acids (such as hydrochloric, hydrobromic, sulfuric, phosphoric, nitric, and the like), organic acids (such as acetic, propionic, succinic, glycolic, stearic, lactic, malic, tartaric, citric, glutamic, aspartic, benzoic, salicylic, oxalic, ascorbic acid, and the like) or bases (such as the hydroxide, carbonate or bicarbonate of a pharmaceutically-acceptable metal cation or organic cations derived from N,N-dibenzylethylenediamine, D-glucosamine, or ethylenediamine). The salts are prepared in a conventional manner, *e.g.,* by neutralizing the free base form of the compound with an acid.

A diketopiperazine of formula **(1)**, or a physiologically-acceptable salt thereof, can be used to treat a disease or condition mediated by PAF. To do so, a diketopiperazine of formula **(1)**, or a physiologically-acceptable salt thereof, is administered to an animal in need of treatment. Preferably, the animal is a mammal, such as a rabbit, goat, dog, cat, horse or human. Effective dosage forms, modes of administration and dosage amounts for the various compounds of the invention may be determined empirically, and making such determinations is within the skill of the art. It is understood by those skilled in the art that the dosage amount will vary with the particular compound employed, the disease or condition to be treated, the severity of the disease or condition, the route(s) of administration, the rate of excretion of the compound, the duration of the treatment, the identify of any other drugs being administered to the animal, the age, size and species of the animal, and like factors known in the medical and veterinary arts. In general, a suitable daily dose of a compound of the present invention will be that amount of the compound which is the lowest dose effective to produce a therapeutic effect. However, the daily dosage will be determined by an attending physician or veterinarian within the scope of sound medical judgment. If desired, the effective daily dose may be administered as two, three, four, five, six or more sub-doses, administered separately at appropriate intervals throughout the day. Administration of the compound should be continued until an acceptable response is achieved.

The compounds of the present invention (*i.e.,* diketopiperazines of formula **(1)** and physiologically-acceptable salts thereof) may be administered to an animal patient for therapy

by any suitable route of administration, including orally, nasally, rectally, vaginally, parenterally (*e.g.*, intravenously, intraspinally, intraperitoneally, subcutaneously, or intramuscularly), intracisternally, transdermally, intracranially, intraccrebrally, and topically (including buccally and sublingually). The preferred routes of administration are orally and intravenously.

While it is possible for a compound of the present invention to be administered alone, it is preferable to administer the compound as a pharmaceutical formulation (composition). The pharmaceutical compositions of the invention comprise a compound or compounds of the invention as an active ingredient in admixture with one or more pharmaceutically-acceptable carriers and, optionally, with one or more other compounds, drugs or other materials. Each carrier must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not injurious to the animal. Pharmaceutically-acceptable carriers are well known in the art. Regardless of the route of administration selected, the compounds of the present invention are formulated into pharmaceutically-acceptable dosage forms by conventional methods known to those of skill in the art. See, *e.g., Remington's Pharmaceutical Sciences*.

Formulations of the invention suitable for oral administration may be in the form of capsules, cachets, pills, tablets, powders, granules or as a solution or a suspension in an aqueous or non-aqueous liquid, or an oil-in-water or water-in-oil liquid emulsions, or as an elixir or syrup, or as pastilles (using an inert base, such as gelatin and glycerin, or sucrose and acacia), and the like, each containing a predetermined amount of a compound or compounds of the present invention as an active ingredient. A compound or compounds of the present invention may also be administered as bolus, electuary or paste.

In solid dosage forms of the invention for oral administration (capsules, tablets, pills, dragees, powders, granules and the like), the active ingredient is mixed with one or more pharmaceutically acceptable carriers, such as sodium citrate or dicalcium phosphate, and/or any of the following: (1) fillers or extenders, such as starches, lactose, sucrose, glucose, mannitol, and/or silicic acid; (2) binders, such as, for example, carboxymethylcellulose, alginates, gelatin, polyvinyl pyrrolidone, sucrose and/or acacia; (3) humectants, such as glycerol; (4) disintegrating agents, such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, and sodium carbonate; (5) solution retarding agents,

such as paraffin; (6) absorption accelerators, such as quaternary ammonium compounds; (7) wetting agents, such as, for example, cetyl alcohol and glycerol monosterate; (8) absorbents, such as kaolin and bentonite clay; (9) lubricants, such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, sodium lauryl sulfate, and mixtures thereof; and (10) coloring agents. In the case of capsules, tablets and pills, the pharmaceutical compositions may also comprise buffering agents. Solid compositions of a similar type may be employed as fillers in soft and hard-filled gelatin capsules using such excipients as lactose or milk sugars, as well as high molecular weight polyethylene glycols and the like.

A tablet may be made by compression or molding optionally with one or more accessory ingredients. Compressed tablets may be prepared using binder (for example, gelatin or hydroxypropylmethyl cellulose), lubricant, inert diluent, preservative, disintegrant (for example, sodium starch glycolate or cross-linked sodium carboxymethyl cellulose), surface-active or dispersing agent. Molded tablets may be made by molding in a suitable machine a mixture of the powdered compound moistened with an inert liquid diluent.

The tablets, and other solid dosage forms of the pharmaceutical compositions of the present invention, such as dragees, capsules, pills and granules, may optionally be scored or prepared with coatings and shells, such as enteric coatings and other coatings well known in the pharmaceutical-formulating art. They may also be formulated so as to provide slow or controlled release of the active ingredient therein using, for example, hydroxypropylmethyl cellulose in varying proportions to provide the desired release profile, other polymer matrices, liposomes and/or microspheres. They may be sterilized by, for example, filtration through a bacteria-retaining filter. These compositions may also optionally contain opacifying agents and may be of a composition that they release the active ingredient only, or preferentially, in a certain portion of the gastrointestinal tract, optionally, in a delayed manner. Examples of embedding compositions which can be used include polymeric substances and waxes. The active ingredient can also be in microencapsulated form.

Liquid dosage forms for oral administration of the compounds of the invention include pharmaceutically-acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. In addition to the active ingredient, the liquid dosage forms may contain inert diluents commonly used in the art, such as, for example, water or other solvents, solubilizing agents and emulsifiers, such as ethyl alcohol, isopropyl alcohol, ethyl carbonate,

ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor and sesame oils), glycerol, tetrahydrofuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan, and mixtures thereof.

Besides inert diluents, the oral compositions can also include adjuvants such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, coloring, perfuming and preservative agents.

Suspensions, in addition to the active compounds, may contain suspending agents as, for example, ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth, and mixtures thereof.

Formulations of the pharmaceutical compositions of the invention for rectal or vaginal administration may be presented as a suppository, which may be prepared by mixing one or more compounds of the invention with one or more suitable nonirritating excipients or carriers comprising, for example, cocoa butter, polyethylene glycol, a suppository wax or salicylate, and which is solid at room temperature, but liquid at body temperature and, therefore, will melt in the rectum or vaginal cavity and release the active compound. Formulations of the present invention which are suitable for vaginal administration also include pessaries, tampons, creams, gels, pastes, foams or spray formulations containing such carriers as are known in the art to be appropriate.

Dosage forms for the topical or transdermal administration of compounds of this invention include powders, sprays, ointments, pastes, creams, lotions, gels, solutions, patches, drops and inhalants. The active ingredient may be mixed under sterile conditions with a pharmaceutically-acceptable carrier, and with any buffers, or propellants which may be required.

The ointments, pastes, creams and gels may contain, in addition to an active ingredient, excipients, such as animal and vegetable fats, oils, waxes, paraffins, starch, tragacanth, cellulose derivatives, polyethylene glycols, silicones, bentonites, silicic acid, talc and zinc oxide, or mixtures thereof.

Powders and sprays can contain, in addition to an active ingredient, excipients such as lactose, talc, silicic acid, aluminum hydroxide, calcium silicates and polyamide powder

or mixtures of these substances. Sprays can additionally contain customary propellants such as chlorofluorohydrocarbons and volatile unsubstituted hydrocarbons, such as butane and propane.

Transdermal patches have the added advantage of providing controlled delivery of compounds of the invention to the body. Such dosage forms can be made by dissolving, dispersing or otherwise incorporating one or more compounds of the invention in a proper medium, such as an elastomeric matrix material. Absorption enhancers can also be used to increase the flux of the compound across the skin. The rate of such flux can be controlled by either providing a rate-controlling membrane or dispersing the compound in a polymer matrix or gel.

Pharmaceutical formulations include those suitable for administration by inhalation or insufflation or for nasal or intraocular administration. For administration to the upper (nasal) or lower respiratory tract by inhalation, the compounds of the invention are conveniently delivered from an insufflator, nebulizer or a pressurized pack or other convenient means of delivering an aerosol spray. Pressurized packs may comprise a suitable propellant such as dichlorodifluoromethane, trichlorofluoromethane, dichlorotetrafluoroethane, carbon dioxide, or other suitable gas. In the case of a pressurized aerosol, the dosage unit may be determined by providing a valve to deliver a metered amount.

Alternatively, for administration by inhalation or insufflation, the composition may take the form of a dry powder, for example, a powder mix of one or more compounds of the invention and a suitable powder base, such as lactose or starch. The powder composition may be presented in unit dosage form in, for example, capsules or cartridges, or, *e.g.*, gelatin or blister packs from which the powder may be administered with the aid of an inhalator, insufflator or a metered-dose inhaler.

For intranasal administration, compounds of the invention may be administered by means of nose drops or a liquid spray, such as by means of a plastic bottle atomizer or metered-dose inhaler. Typical of atomizers are the Mistometer (Wintrop) and Medihaler (Riker).

Drops, such as eye drops or nose drops, may be formulated with an aqueous or nonaqueous base also comprising one or more dispersing agents, solubilizing agents or

suspending agents. Liquid sprays are conveniently delivered from pressurized packs. Drops can be delivered by means of a simple eye dropper-capped bottle or by means of a plastic bottle adapted to deliver liquid contents dropwise by means of a specially shaped closure.

Pharmaceutical compositions of this invention suitable for parenteral administrations comprise one or more compounds of the invention in combination with one or more pharmaceutically-acceptable sterile isotonic aqueous or non-aqueous solutions, dispersions, suspensions or emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or dispersions just prior to use, which may contain antioxidants, buffers, solutes which render the formulation isotonic with the blood of the intended recipient or suspending or thickening agents.

Examples of suitable aqueous and nonaqueous carriers which may be employed in the pharmaceutical compositions of the invention include water, ethanol, polyols (such as glycerol, propylene glycol, polyethylene glycol, and the like), and suitable mixtures thereof, vegetable oils, such as olive oil, and injectable organic esters, such as ethyl oleate. Proper fluidity can be maintained, for example, by the use of coating materials, such as lecithin, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants.

These compositions may also contain adjuvants such as wetting agents, emulsifying agents and dispersing agents. It may also be desirable to include isotonic agents, such as sugars, sodium chloride, and the like in the compositions. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents which delay absorption such as aluminum monosterate and gelatin.

In some cases, in order to prolong the effect of a drug, it is desirable to slow the absorption of the drug from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material having poor water solubility. The rate of absorption of the drug then depends upon its rate of dissolution which, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally-administered drug is accomplished by dissolving or suspending the drug in an oil vehicle.

Injectable depot forms are made by forming microencapsule matrices of the drug in biodegradable polymers such as polylactide-polyglycolide. Depending on the ratio of drug

to polymer, and the nature of the particular polymer employed, the rate of drug release can be controlled. Examples of other biodegradable polymers include poly(orthoesters) and poly(anhydrides). Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions which are compatible with body tissue. The injectable materials can be sterilized for example, by filtration through a bacterial-retaining filter.

The formulations may be presented in unit-dose or multi-dose sealed containers, for example, ampules and vials, and may be stored in a lyophilized condition requiring only the addition of the sterile liquid carrier, for example water for injection, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets of the type described above.

As noted above, PAF has been reported to play a role in a variety of diseases and conditions. These diseases and conditions include acute respiratory distress syndrome, allergies, arthritis, asthma, autoimmune diseases, bronchitis, cardiovascular disease, Crohn's disease, cystic fibrosis, emphysema, gastrointestinal ulceration, inflammation, inflammatory bowel disease, ischemia, multiple organ dysfunction syndrome, myocardial infarction, neoplastic diseases, ophthalmic inflammation, pain, psoriasis, respiratory infections, sepsis, shock, and ulcerative colitis. PAF also mediates platelet aggregation. The diketopiperzines of formula **(1)** can be used to treat any of these diseases and conditions and any other diseases and conditions in which PAF plays a role. The compounds of the invention can be given in combination with other standard therapies for a given disease or condition.

PAF has been reported to induce the production and secretion of interleukin 8 (IL-8) (see discussion in Example 3 below). IL-8 is a pro-inflammatory cytokine which has been reported to play a role in the pathogenesis of a large number of diseases and conditions, including acute respiratory distress syndrome, allergies, arthritis, asthma, autoimmune diseases, bronchitis, cancer, Crohn's disease, cystic fibrosis, emphysema, endocarditis, gastritis, inflammatory bowel disease, ischemia reperfusion, multiple organ dysfunction syndrome, nephritis, pancreatitis, respiratory viral infections, sepsis, shock, ulcerative colitis, and other inflammatory disorders. The diketopiperazines of formula **(1)** have been found to inhibit the PAF-induced production and/or release of IL-8. Preliminary data indicate that they also inhibit the production and/or release of IL-8 in the absence of PAF. In particular, it has been found that the lipopolysaccharide (LPS)-induced production and/or release of IL-8

by normal human bronchial epithelial cells is inhibited (data not shown). Thus, the diketopiperazines of the invention appear to act by two different mechanisms and may be used to treat diseases or conditions mediated by IL-8, as well as PAF.

EXAMPLES

Example 1: Preparation of 3-Methyl-2,5-Diketopiperazine-6-Acetic Acid (5)

Wang resin having 9-fluorenylmethyloxycarbonyl-protected alanine (Ala-Fmoc) attached thereto (3 grams (g), 2.52 mmol, 1 equivalent, NovaBiochem) was transferred to a clean round-bottom, 100 mL flask, and a solution of piperidine (12 mL) in dimethylformamide (DMF; 18 mL) was added to the resin in the flask. The solution was swirled for 1 hour, and the resin was isolated in a sintered glass funnel. The resin was washed with DMF (3 x 30 mL) followed by dichloromethane (DCM; 3 x 30 mL) and allowed to dry under vacuum for 5 minutes.

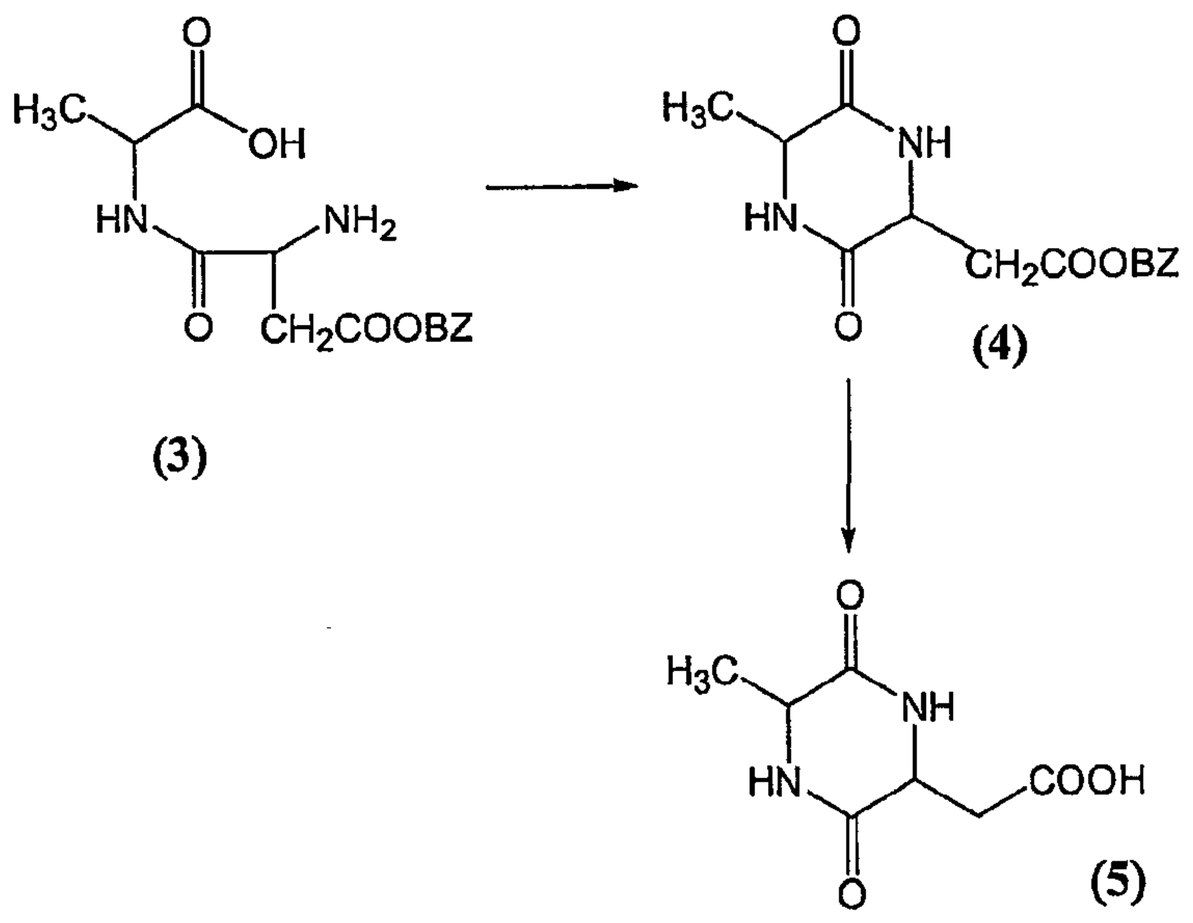
The partially-dried resin was transferred into a clean round-bottom, 100 mL flask, and DMF (10 mL) was added. Then, Boc-Asp(OBz)OH (3.25 g,10.07 mmol, 4 equivalents) was added, followed by diisopropylamine (2.83 mL, 2.04 g, 20.19 mmol, 8 equivalents) and 2-(1H-benzotriazole-1-yl)-1,2,3,3-tetramethyluroniumtetrafluoroborate (TBTU; 3.24 g,10.09 mmol, 4 equivalents, Acros). The slurry was allowed to react under anaerobic conditions over 12 hours. At the end of this time, the resin showed a negative ninhydrin test, indicating the completion of the coupling reaction. The resin was vacuum filtered and washed with DMF (3 x 30 mL) followed by DCM (3 x 30 mL). The resin was allowed to dry at room temperature under vacuum for 10 minutes before transferring it into a clean round-bottom,100 mL flask.

Trifluoroacetic acid (TFA; 16.5 mL) was added to the dried resin and, upon its addition, the resin turned a red color. After swirling the resin for a further 30 minutes, TFA was removed by filtration, and the resin was washed with DCM (4 x 20 mL). The organic components were pooled, and toluene (20 mL) was added. The combined organic materials were evaporated to dryness under vacuum. Traces of TFA were removed by the addition of toluene and evaporation. The process was repeated until all TFA had been removed. This procedure resulted in a product as a pale yellow oil whose NMR and mass

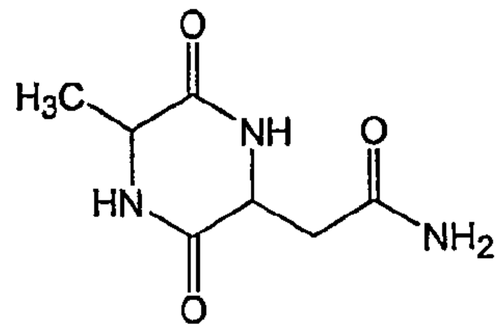
spectrophotometric data were consistent with the expected dipeptide benzyl ester whose structure (3) is shown below.

The dipeptide 3 was dissolved in butan-2-ol (40 mL) and diluted with toluene (60 mL). This solution was allowed to reflux for 24 hours. At the end of this period, the solution was allowed to cool to room temperature. It was then concentrated on a rotary evaporator, while maintaining the temperature at 50°C. Upon concentration, a white solid precipitated, and the precipitate was removed by filtration. The precipitate was washed with toluene (10 mL) and dried. The residue (0.650 g) gave a negative ninhydrin test. It was, then, crystallized from hot methanol. The spectroscopic and analytical results for the crystallized product confirmed its structure to be the desired compound - Asp-Ala diketopiperazine-benzyl ester shown below (4).

This compound (400 mg) was dissolved in methanol (250 mL), and palladium on carbon catalyst (Pd/C; 10%, 0.4g) was added carefully. The flask was purged with hydrogen and kept at a positive hydrogen pressure. The solution was kept in this atmosphere for at least 4 hours. The catalyst was removed with a filtering aid (celite) and washed with methanol. The methanol washings were combined, and the solvent was removed (yield 200 mg). Mass spectrometer and NMR analysis showed that the free acid Asp-Ala diketopiperazine (3-methyl-2,5- diketopiperazine-6-acetic acid, 5) had formed without any cross contamination.



Example 2: Preparation Of Asp-Ala Diketopiperazine Amide (6)



(6)

To a solution of 3-methyl-2,5- diketopiperazine-6-acetic acid (0.151 g, 0.81 mmol, 1 equivalent, preparation described in Example 1, **5**) in DMF (2.5 mL) was added carbonyl diimidazole (0.26 g, 1.60 mmol, 2 equivalents, Aldich). After stirring at room temperature for 1 hour, solid ammonium acetate (0.63 g, 8.17 mmol, 10 equivalents, Aldrich) was added. Stirring at room temperature was continued overnight, at which time the reaction was partitioned between water (20 mL) and ethyl acetate (10 mL). The aqueous layer was washed with a second aliquot of ethyl acetate (10 mL) and then evaporated to dryness under reduced pressure (61°C). Traces of DMF were removed by further co-evaporations with water and then toluene to give a white solid (362 mg). This was taken up into a minimum volume of methanol in DCM (20:80 v/v). The solvent eluted was fractionated, and the appropriate fractions were pooled and evaporated under reduced pressure (40°C) to give a white solid. The product was then recrystallized from methanol to given the desired product (0.116 g, 76% yield, **6**).

Example 3: Inhibition of Release of IL-8

Interleukin 8 (IL-8) is a pro-inflammatory cytokine and a potent chemoattractant and activator of neutrophils. It has also been reported to be a chemoattractant and activator of T-lymphocytes and eosinophils. IL-8 is produced by immune cells (including lymphocytes, neutrophils, monocytes and macrophages), fibroblasts and epithelial cells. Reports indicate an important role for IL-8 in the pathogenesis of respiratory viral infections, asthma, bronchitis, emphysema, cystic fibrosis, acute respiratory distress syndrome, sepsis, multiple organ dysfunction syndrome, and other inflammatory disorders.

It has been reported that PAF induces the transcription and secretion of IL-8 in human lung fibroblasts. Roth et al., *J. Exp. Med.*, **184**, 191-201 (1996). It has also been reported that PAF enhances the production of IL-8 by human mononuclear cells in response to

lipopolysaccharide (LPS), but that PAF alone only weakly induces the production of IL-8 by these cells. Arbabi et al., *Archives Surgery*, **134**, 1348-1353 (1999). These authors hypothesize that PAF "primes" the innate immune system to produce enhanced amounts of proinflammatory mediators in response to a second inflammatory stimulus that otherwise would have been insufficient to trigger an inflammatory response. They further speculate that if this priming is generalized, it may become harmful. In such a case, the second stimulus, which would be considered minor by the unprimed innate immune system, would induce an aggressive, diffuse, and nonfocused release of inflammatory mediators, possibly leading to multiple organ dysfunction syndrome.

NHBE 6122 normal human bronchial epithelial cells (Clonetics, San Diego, CA) were added to a 24-well tissue culture plate (Falcon, now BD Biosciences, Franklin Lakes, NJ) at 20,000 cells/well and allowed to adhere overnight (16-18 hours) in BEGM (bronchial epithelial growth medium; Clonetics) containing epinephrine (complete medium) at 37 °C and 5% CO_2. After adhering, the cells were washed twice with BEGM medium without epinephrine. They were then incubated in complete medium or in complete medium containing 20 μM 3-methyl-2,5-diketopiperazine-6-acetic acid (DA-DKP; preparation described in Example **1, 5**; stock solution made in HEPES buffered saline (HBSS; Clonetics) at 4 mM for 20 minutes at 37 °C and 5% CO_2. Platelet activating factor (PAF; Sigma, St. Louis, MO) dissolved in dimethylsulfoxide (DMSO; tissue culture grade; Sigma, St. Louis, MO) was then added to a final concentration of 100 nM or 500 nM, and the cells were incubated for an additional 6 hours at 37 °C and 5% CO_2. Medium containing DMSO and HBSS was used as a control.

The concentration of IL-8 in cell supernatants was determined by an ELISA using human IL-8 matched pair antibodies (Endogen, Cambridge, MA). The ELISA was performed using an ELISA kit from Endogen, Cambridge, MA according to the manufacturer's instructions with the following exceptions: (1) coating antibody at 1 μg/ml; (2) detecting antibody 30 ng/ml; StrepAvidin HRP diluted 1:32,000.

The results are presented in Tables 1-3 below. As can be seen, IL-8 secretion induced by PAF in NHBE 6122 cells was inhibited by the pre-incubation of the cells with DA-DKP. It is hypothesized that the DA-DKP binds to PAF, the PAF receptor, or both, blocking the signal to produce (release) IL-8.

TABLE 1

	IL-8 (pg/ml)	SEM
DMSO	729.88	8.46
HBSS	809.62	198.23
DA-DKP (20 μM)	803.11	67.17
PAF (100 nM)	1094.68	103.21
PAF + DA-DKP	714.91	88.95

TABLE 2

	IL-8 (pg/ml)	SEM
DMSO	602.99	73.48
HBSS	581.86	64.36
DA-DKP (20 μM)	837.84	100.73
PAF (500 nM)	887.87	112.56
PAF + DA-DKP	542.5	37.17

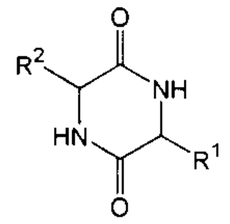
TABLE 3

	IL-8 (pg/ml)	SEM
DMSO	209.79	13.24
HBSS	233.08	5.79
DA-DKP (20 μM)	184.86	34.73
PAF (100 nM)	355.36	11.28
PAF + DA-DKP	201.93	20.64

* For Table 3, cells were split to give 5,000 cells/well four days prior to the experiment and were allowed to grow to 70% confluence.

WE CLAIM:

1. Use of an active ingredient for the manufacture of a medicament for inhibiting ophthalmic inflammation, wherein the active ingredient has the following formula:



wherein:

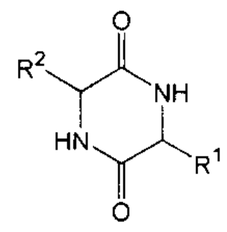
R^1 is $-CH_2COR^3$;

R^2 is the side chain of alanine;

R^3 is -OH; or

a physiologically-acceptable salt thereof.

2. A pharmaceutical composition formulated for ocular administration comprising a pharmaceutically-acceptable carrier and an active ingredient having the formula:



wherein:

R^1 is $-CH_2COR^3$;

R^2 is the side chain of alanine;

R^3 is -OH-; or

a physiologically-acceptable salt thereof.

3. The composition according to claim 2 which is drops.