Abstract:
The present invention relates to a method for reducing the production of methane emanating from the digestive activities of a ruminant and/or for improving ruminant animal performance by using, as active compound at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof, which is administrated to the animal together with the feed. The invention also relates to the use of these compounds in feed and feed additives such as premix, concentrates and total mixed ration (TMR) or in the form of a bolus.
USE OF NITROOXY ORGANIC MOLECULES IN FEED FOR REDUCING METHANE EMISSION IN RUMINANTS, AND/OR TO IMPROVE RUMINANT PERFORMANCE

The present invention relates to the use of at least one organic molecule substituted at any position with at least one nitrooxy group for reducing the production of methane emanating from the digestive activities of ruminants, and/or to improve the ruminant performance.

The present invention also relates to animal feed or animal feed compositions and feed additives comprising the above mentioned molecules. The term feed or feed composition means any compound, preparation, mixture, or composition suitable for, or intended for intake by an animal.

In the present context, a ruminant is a mammal of the order Artiodactyla that digests plant-based food by initially softening it within the animal's first stomach, known as the rumen, then regurgitating the semi-digested mass, now known as cud, and chewing it again. The process of again chewing the cud to further break down plant matter and stimulate digestion is called "ruminating".

Rumen fermentation brings some disadvantages. Methane is produced as a natural consequence of the anaerobic fermentation, which represents an energy loss to the host animal. Carbohydrate makes up 70 - 80% of the dry matter in a typical dairy cattle ration and in spite of this the absorption of carbohydrates from the gastrointestinal tract is normally very limited. The reason for this is the extensive fermentation of carbohydrates in the rumen resulting in production of acetate, propionate and
butyrate as the main products. These products are part of the so called volatile fatty acids, (VFAs).

Besides the energy loss, methane is also a greenhouse gas, which is many times more potent than CO2. Its concentration in the atmosphere has doubled over the last century and continues to increase alarmingly. Ruminants are the major contributors to the biogenic methane formation, and it has been estimated that the prevention of methane formation from ruminants would almost stabilize atmospheric methane concentrations.

Furthermore, the assessment of the Kyoto protocol followed by the Copenhagen climate summit in 2009 places increased priority in decreasing methane emissions as part of a multi-gas strategy. The most effective additives currently used for reducing the formation of methane contain antibiotics which diminish the proliferation of microorganisms providing hydrogen (H₂) to the methanogens (Sauer et al. 1998. American Society of Animal Science; 76: 906-914). However, the effect of antibiotics on the formation of methane has some disadvantages because of rapid adaptation of the microflora and/or resistance development leading to a complete loss of the intended effect within a short period of time (2 to 3 weeks), and because the use of antibiotics is banned in Europe for non therapeutic use.

Non antibiotic products (bile acid derivatives) leading to reduction of methane emission, when tested using an in vitro rumen simulation model, have recently been published (WO 2010072584). However, the amount required to produce a moderate reduction of methane emission are not compatible with the ruminant feed industry cost constraints.

Furthermore, a number of natural plant extracts (Garlic: WO 2009150264, yucca, cinnamon, rhubarb... ) have been described in the scientific literature as potent solutions to reduce methane emission in ruminants based on in vitro experiments. However, none of these solutions made it to a commercial product because of side effects (residues in milk), because of lack efficacy, when tested in vivo, or because of
the very large amount of additive which needs to be supplied to the animal to generate a significant methane reduction.

Under these circumstances there is still a need to develop new substances which reduce the formation of methane and which are in line with reliable and generally accepted practice and not of a medicinal nature. In addition to reducing methane emission, such substances may also contribute to improve ruminant performance by improving the feed conversion ratio, reducing feed intake, improving weight gain, and/or improving carcass, or milk yield.

The present inventors now surprisingly found that the compounds specified herein after, have a great potential for use in animal feed in order to essentially reduce the formation of methane without affecting microbial fermentation in a way that would be detrimental to the host animal. Moreover, the compounds of the present invention also have a great benefit regarding overall animal performance as measured by feed conversion ratio, feed intake, weight gain, carcass yield, or milk yield. Said compounds are also more stable than those described in the prior art, safer for the animal and human, lead to persistent methane reduction effect, they do not affect palatability, they can be produced at industrial scale at a cost compatible with the animal nutrition industry, and above all, they do not provoke accumulation of any metabolite in the milk or meat of the supplemented animal, and they are active at very low concentration in the rumen.

In particular, the present inventors have observed that the feeding to ruminants of at least one organic molecule substituted at any position with at least one nitrooxy group is very effective for reducing the production of methane emanating from the digestive activities of ruminants without negatively affecting total VFA production, and/or for improving the ruminant performance. Moreover, the present inventors have shown that when the nitrooxy group is replaced by other chemical groups of similar physicochemical properties, the technical effect on methane production is lost demonstrating that the Nitrooxy group is key for the effect on methane reduction of the present invention.
It is known from the international patent application Nr.: PCT/EP2010/069338 that nitrooxy-carboxylic acid derivatives are potent inhibitors of rumen methanogenesis \textit{in vitro}, and also \textit{in vivo}. Therefore, these molecules are specifically disclaimed from the present invention.

Therefore, the present invention provides the use of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I) as an active compound in animal feeding for reducing the formation of methane emanating from the digestive activities of ruminants and/or for improving ruminant performance.

The invention further provides a method for reducing the production of methane emanating from the digestive activities of ruminants and/or for improving ruminant animal performance, comprising orally administering a sufficient amount of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I) to the animal. It is to be understood by oral administration a simple feeding, or manual administration of a bolus.

In all embodiments of the present invention, organic molecules substituted at any position with at least one nitrooxy group, or salts thereof are defined by the following compound of formula (I)

\[
O_2N\overset{\text{Y}}{\rightarrow} \text{formula (I)}
\]

wherein \(Y\) is an organic molecule of the following composition: \(C_aH_bO_dN_eS_g\),

wherein
- \(a\) is comprised between 1 and 25, preferably between 1 and 10
- \(b\) is comprised between 2 and 51, preferably between 2 and 21
- \(d\) is comprised between 0 and 8, preferably between 0 and 6
- \(e\) is comprised between 0 and 5, preferably between 0 and 3
g is comprised between 0 and 3, preferably between 0 and 1,

wherein nitrooxy alkanoic acid, and/or derivatives thereof as defined by the formula (II) are excluded,

\[
\begin{align*}
\text{O}_2\text{N} & \quad \text{O} \\
R_2 & \quad \text{u} \quad \text{Z} \quad R_1 \\
\text{R}_2 & \quad \text{R}_2 & \quad \text{Z} & \quad \text{R}_1 \\
\text{formula (II)}
\end{align*}
\]

wherein

- u is comprised between 0 and 23 and, wherein if \( u \neq 0 \), the carbon chain is a linear, a cyclic, or branched linear or cyclic aliphatic carbon chain which may be mono- or polyunsaturated and in any isomeric form,
- Z is independently 0, NH, or N-R3, wherein if \( R_1 \neq H \), Z-R1 represents an ester or a secondary amide derivative,
- R1 is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 10 carbon atoms,
- R2 is independently, hydrogen or a saturated straight or branched chain of an alkyl or alkenyl group containing 1 to 23 carbon atoms, and
- R3 is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 10 carbon atoms.

In another embodiment, preferred compounds of formula (I) according to the present invention are compounds, wherein \( a \) is comprised between 1 and 10, preferably, \( a \) is comprised between 3 and 8.

In another embodiment, preferred compounds of formula (I) according to the present invention are compounds of formula (III),
wherein

\( n \) is comprised between 0 and 12, preferably comprised between 0 and 6 and, wherein, if \( n \neq 0 \), the carbon chain is a linear, a cyclic, or branched aliphatic carbon chain which may be non substituted or substituted with up to 3 hydroxyl-, alkoxy-, amino-, alkylamino-, dialkylamino- or nitrooxy groups, or an alkenyl, or an alkynyl carbon chain mono- or polyunsaturated and in any isomeric form,

\( R_4 \) is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 12, preferably 1 to 6 carbon atoms,

\( X \) is hydrogen, \( R_5, R_5=\text{N} \), -OR5, -OCOR5, -N(R5)R6, -ON02, -COOR5, -CON(R5)R6, -NHS02R5, or -S02NHR5,

\( R_5 \) and \( R_6 \) are independently, hydrogen, C1-C12 straight, branched or cyclic alkyl chain, non substituted or substituted with up to 3 hydroxyl-, alkoxy-, amino-, alkylamino-, dialkylamino- or nitrooxy groups, alkenyl, or alkynyl carbon chain which may be mono or polyunsaturated, and in any isomeric form.

For all embodiments of the present invention, it is to be understood that compounds of formula (I) and compounds of formula (III) can be in any isomeric form.

It is to be understood in the above definition of compounds of formula (III) that when \( n > 2 \), the carbon chain can be linear or branched at any position along the carbon chain. In addition, the carbon chain can be branched by multiple branches at different positions along the carbon chain. Moreover, when \( n > 3 \), the aliphatic carbon chain may form a cyclic moiety. This cyclic moiety can carry the nitrooxy moiety at any position (2, 3, 4), and it can also be branched at multiple positions by any aliphatic groups. The branched aliphatic groups are preferably, methyl, ethyl or propyl.
Moreover, the carbon chain may be further substituted with up to 3 hydroxyl-, alkoxy-, amino-, alkylamino-, dialkylamino- or nitrooxy groups.

In the above definition of derivatives of the formula (III) a preferred alkyl group is methyl, ethyl, propyl, isopropyl, butyl, sec. butyl, isobutyl, pentyl, neopentyl, hexyl, cyclohexyl, and 2-ethyl-hexyl and octyl. Furthermore any alkyl or alkenyl group containing three or more carbon atoms can be straight chain, branched, or cyclic. In addition for the straight chain or branched C2-Cio-alkenylene group, this is understood to encompass alkenylene groups with one or (from C4) more double bonds; examples of such alkenylene groups are those of the formulae -CH=CH-, -CH=CH-CH2-, -CH=CH-(CH2)3- and -(CH=CH)2-.

In another embodiment, more preferred compounds of formula (I) according to the present invention are selected from the list of compounds, and salts thereof comprising: 3-Nitrooxypropanol, racemate-4-Phenylbutane-1,2-diyl dinitrate, 2-(Hydroxymethyl)-2-(nitrooxymethyl)-1,3-propanediol, N-Ethyl-3-nitrooxy-propionic sulfonyl amide, 5-Nitrooxy-pentanenitrile, 5-Nitrooxy-pentane, 3-Nitrooxy-propyl propionate, 1,3-bis-Nitrooxypropane, 1,4-bis-Nitrooxybutane, 1,5-bis-Nitrooxypentane, 3-Nitrooxy-propyl benzoate, 3-Nitrooxy-propyl hexanoate, 3-Nitrooxy-propyl 5-nitrooxy-hexanoate, Benzyl nitrate, isosorbide-dinitrate, and N-[2-(Nitrooxy)ethyl]-3-pyridinecarboxamide, 2-Nitro-5-nitrooxymethyl-furan, and Bis-(2-nitrooxyethyl) ether as listed in Table 1:

<table>
<thead>
<tr>
<th>Comp. Identifier</th>
<th>Molecular structure</th>
<th>Chemical name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><img src="image1" alt="Molecular structure" /></td>
<td>3-Nitrooxypropanol</td>
</tr>
<tr>
<td>2</td>
<td><img src="image2" alt="Molecular structure" /></td>
<td>rac-4-Phenylbutane-1,2-diyl dinitrate</td>
</tr>
<tr>
<td>No.</td>
<td>Chemical Structure</td>
<td>Description</td>
</tr>
<tr>
<td>-----</td>
<td>-------------------</td>
<td>---------------------------------------</td>
</tr>
<tr>
<td>3</td>
<td><img src="image3.png" alt="Structure 3" /></td>
<td>2-(Hydroxymethyl)-2-(nitrooxymethyl)-1,3-propanediol</td>
</tr>
<tr>
<td>4</td>
<td><img src="image4.png" alt="Structure 4" /></td>
<td>N-Ethyl-3-nitrooxy-propionic sulfonyl amide</td>
</tr>
<tr>
<td>5</td>
<td><img src="image5.png" alt="Structure 5" /></td>
<td>5-Nitrooxy-pentanenitrile</td>
</tr>
<tr>
<td>6</td>
<td><img src="image6.png" alt="Structure 6" /></td>
<td>5-Nitrooxy-pentane</td>
</tr>
<tr>
<td>7</td>
<td><img src="image7.png" alt="Structure 7" /></td>
<td>3-Nitrooxy-propyl propionate</td>
</tr>
<tr>
<td>8</td>
<td><img src="image8.png" alt="Structure 8" /></td>
<td>1,3-bis-Nitrooxypropane</td>
</tr>
<tr>
<td>9</td>
<td><img src="image9.png" alt="Structure 9" /></td>
<td>1,4-bis-Nitrooxybutane</td>
</tr>
<tr>
<td>10</td>
<td><img src="image10.png" alt="Structure 10" /></td>
<td>1,5-bis-Nitrooxypentane</td>
</tr>
<tr>
<td>11</td>
<td><img src="image11.png" alt="Structure 11" /></td>
<td>3-Nitrooxy-propyl benzoate</td>
</tr>
<tr>
<td>12</td>
<td><img src="image12.png" alt="Structure 12" /></td>
<td>3-Nitrooxy-propyl hexanoate</td>
</tr>
<tr>
<td>13</td>
<td><img src="image13.png" alt="Structure 13" /></td>
<td>3-Nitrooxy-propyl 5-nitrooxy-hexanoate</td>
</tr>
<tr>
<td>14</td>
<td><img src="image14.png" alt="Structure 14" /></td>
<td>Benzyl nitrate</td>
</tr>
</tbody>
</table>
In another embodiment, even more preferred compounds of formula (III) based on the strength of their effect in reducing methane are selected from the list of compounds, and salts thereof comprising: 3-Nitroxypropanol, 5-Nitroxy-pentanenitrile, 5-Nitroxy-pentane, 3-Nitroxy-propyl propionate, 1,3-bis-Nitroxypropene, 1,4-bis-Nitroxybutane, 1,5-bis-Nitroxypentane, 3-Nitroxy-propyl benzoate, 3-Nitroxy-propyl hexanoate, 3-Nitroxy-propyl 5-nitroxy-hexanoate, isosorbid-dinitrate, and N-[2-(Nitroxy)ethyl]-3-pyridinecarboxamide, and Bis-(2-nitrooxyethyl) ether as listed in Table 2:

Table 2: Most preferred compounds of formula (I) according to the present invention
<table>
<thead>
<tr>
<th>Comp. Identifier</th>
<th>Molecular structure</th>
<th>Chemical name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HO-CH₂-O-NO₂</td>
<td>3-Nitrooxypropanol</td>
</tr>
<tr>
<td>5</td>
<td>O₂N-O-CH₂-C≡N</td>
<td>5-Nitrooxy-pentanenitrile</td>
</tr>
<tr>
<td>6</td>
<td>O₂N-O-CH₂-CO-CH₂</td>
<td>5-Nitrooxy-pentane</td>
</tr>
<tr>
<td>7</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>3-Nitrooxy-propyl propionate</td>
</tr>
<tr>
<td>8</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>1,3-bis-Nitrooxypropane</td>
</tr>
<tr>
<td>9</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>1,4-bis-Nitroxybutane</td>
</tr>
<tr>
<td>10</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>1,5-bis-Nitrooxypentane</td>
</tr>
<tr>
<td>11</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>3-Nitrooxy-propyl benzoate</td>
</tr>
<tr>
<td>12</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>3-Nitrooxy-propyl hexanoate</td>
</tr>
<tr>
<td>13</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>3-Nitroxy-propyl 5-nitrooxy-hexanoate</td>
</tr>
<tr>
<td>15</td>
<td>O₂N-O-CH₂-CO-CH₂-O₂ N₂</td>
<td>Isosorbid-dinitrate</td>
</tr>
</tbody>
</table>
In another embodiment, most preferred compound of formula (I) based on the strength of their effect in reducing methane and on the production process is a mixture of 3-nitrooxy propanol and 1,3-bis-nitrooxypropane. Preferably the ratio 3-nitrooxy propanol / 1,3-bis-nitrooxypropane is comprised between 1/1 0 and 1000/1, more preferably, between 1/5 and 100/1, most preferably, between 1/1 and 10/1.

The compounds of the present invention also comprise salts of the nitrooxy organic molecule. Preferred cations for salt preparation may be selected from the group consisting of sodium (Na⁺), potassium (K⁺), lithium (Li⁺), magnesium (Mg²⁺), calcium (Ca²⁺), barium (Ba²⁺), strontium (Sr²⁺), and ammonium (NH₄⁺). Salts may also be prepared from an alkali metal or an alkaline earth metal.

The compounds of the present invention can be manufactured in principle according to synthetic methods known per se for nitrooxy organic molecules, and/or based on methods as described in the examples.

In all these cases appropriate methods to purify the product (compounds of formula (I)) can be chosen by those skilled in the art, i.e. by column chromatography, or the compound of formula (I), can be isolated and purified by methods known per se, e.g. by adding a solvent such as diethyl-ether or ethyl acetate to induce the

<table>
<thead>
<tr>
<th>No.</th>
<th>Structure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td><img src="image" alt="Structure" /></td>
<td>N-[2-(Nitrooxy)ethyl]-3-pyridinecarboxamide</td>
</tr>
<tr>
<td>18</td>
<td><img src="image" alt="Structure" /></td>
<td>Bis-(2-nitrooxyethyl) ether</td>
</tr>
</tbody>
</table>
separation of the crude product from the mixture after reaction, and drying over \( \text{Na}_2\text{SO}_4 \) of the collected crude product.

Methane emission by ruminants can easily be measured in individual animals in metabolic chambers by methods known in the art (Grainger et al., 2007 J. Dairy Science; 90: 2755-2766). Moreover, it can also be assessed at barn level by an emerging technology using laser beam (McGinn et al., 2009, Journal of Environmental Quality; 38: 1796-1802). Alternatively, methane produced by a dairy ruminant can also be assessed by measurement of VFA profiles in milk according to WO 2009/1 56453.

Ruminant performance can be assessed by methods well known in the art, and is usually characterized by feed conversion ratio, feed intake, weight gain, carcass yield, or milk yield.

The present invention also relates to the use of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I) in combination with at least one additional active substance which shows similar effects with regard to methane formation in the rumen and which is selected from the group consisting of diallyl disulfide, garlic oil, allyl isothiocyanate, deoxycholic acid, chenodeoxycholic acid and derivatives thereof.

Further components that could be given together with the compound according to the present invention are for example yeasts, essential oils, and ionophores like Monensin, Rumensin.

It is at present contemplated that diallyl disulfide, garlic oil, allyl isothiocyanate deoxycholic acid, chenodeoxycholic acid and derivatives thereof are independently administered in dosage ranges of for example 0.01 -500 mg active substance per kg feed (ppm). These compounds are either commercially available or can easily be prepared by a skilled person using processes and methods well-known in the prior art.
Ruminating mammals according to the present invention include cattle, goats, sheep, giraffes, American Bison, European bison, yaks, water buffalo, deer, camels, alpacas, llamas, wildebeest, antelope, pronghorn, and nilgai.

For all embodiments of the present invention, domestic cattle, sheep and goat are the more preferred species. For the present purposes most preferred species are domestic cattle. The term includes all races of domestic cattle, and all production kinds of cattle, in particular dairy cows and beef cattle.

The present invention also relates to the use of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I), wherein the methane production in ruminants calculated in liters per kilogram of dry matter intake is reduced by at least 10 % when measured in metabolic chambers. Preferably, methane reduction is at least 15 %, more preferably, at least 20 %, even more preferably, at least 25 %, most preferably, at least 30 %. Alternative methane emission measurements may also be used like using a laser beam or for dairy ruminants, correlating methane production to the VFA profile in milk.

The present invention also relates to the use of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I), wherein the ruminant feed conversion ratio is reduced by at least 1 % when measured in conventional performance trial. Preferably, the feed conversion ratio is reduced by at least 2 %, more preferably, by at least 2.5 %, even more preferably, by at least 3 %, most preferably, by at least 3.5 %.

The present invention also relates to the use of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I), wherein the amount of the at least one active compound as defined in formula (I) administered to the ruminant animal is from 1 mg to 10 g per Kg of feed, preferably from 10 mg to 1 g per Kg of feed, more preferably, from 50 mg to 500 mg.
per Kg of feed. For the use in animal feed, however, organic molecules substituted at any position with at least one nitrooxy group, or their salts thereof as defined by formula (I) need not be that pure; it may e.g. include other compounds and derivatives.

As indicated above, the compounds of the present invention are useful as compounds for feed additives and animal feed compositions for ruminants, and accordingly are useful as the active ingredients in such feed to reduce methane formation in the digestive tract of the animal, and/or to improve ruminant performance.

For the realisation of their use as such ingredients for the feed of ruminants the compounds may be incorporated in the feed by methods known per se in the art of feed formulation and processing.

Further aspects of the present invention are therefore formulations, i.e. feed additives and animal feed compositions containing compounds as herein above defined. The present invention therefore also relates to a feed composition or a feed additive comprising at least one compound of formula (I) or a salt thereof. Preferably, the feed composition or feed additive is a ruminant base mix. In a preferred embodiment, the composition is a mineral premix, a vitamin premix including vitamins and minerals or a bolus.

The normal daily dosage of a compound according to the invention provided to an animal by feed intake depends upon the kind of animal and its condition. Normally this dosage should be in the range of from about 1 mg to about 10 g, preferably from about 10 mg to about 1 g, more preferably, 50 mg to 500 mg compound per kg of feed.

The at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I) may be used in combination with conventional ingredients present in an animal feed composition (diet) such as calcium carbonates, electrolytes such as ammonium chloride, proteins such as soya
bean meal, wheat, starch, sunflower meal, corn, meat and bone meal, amino acids, animal fat, vitamins and trace minerals.

Particular examples of compositions of the invention are the following:

- An animal feed additive comprising (a) at least one compound selected from table 1 and (b) at least one fat-soluble vitamin, (c) at least one water-soluble vitamin, (d) at least one trace mineral, and/or (e) at least one macro mineral;

- An animal feed composition comprising at least one compound selected from table 1 and a crude protein content of 50 to 800 g/kg feed.

Therefore, in a preferred embodiment, the present invention relates to a ruminant feed composition or feed additive.

The so-called premixes are examples of animal feed additives of the invention. A premix designates a preferably uniform mixture of one or more micro-ingredients with diluents and/or carrier. Premixes are used to facilitate uniform dispersion of micro-ingredients in a larger mix.

Apart from the active ingredients of the invention, the premix of the invention contains at least one fat-soluble vitamin, and/or at least one water soluble vitamin, and/or at least one trace mineral, and/or at least one macro mineral. In other words, the premix of the invention comprises the at least one compound according to the invention together with at least one additional component selected from the group consisting of fat-soluble vitamins, water-soluble vitamins, trace minerals, and macro minerals.

Macro minerals may be separately added to the feed. Therefore, in a particular embodiment, the premix comprises the active ingredients of the invention together with at least one additional component selected from the group consisting of fat-soluble vitamins, water-soluble vitamins, and trace-minerals.

The following are non-exclusive lists of examples of these components:
- Examples of fat-soluble vitamins are vitamin A, vitamin D3, vitamin E, and vitamin K, e.g. vitamin K3.
- Examples of water-soluble vitamins are vitamin B12, biotin and choline, vitamin B1, vitamin B2, vitamin B6, niacin, folic acid and panthothenate, e.g. Ca-D-panthothenate.
- Examples of trace minerals are manganese, zinc, iron, copper, iodine, selenium, and cobalt.
- Examples of macro minerals are calcium, phosphorus and sodium.

As regards feed compositions for ruminants such as cows, as well as ingredients thereof, the ruminant diet is usually composed of an easily degradable fraction (named concentrate) and a fiber-rich less readily degradable fraction (named hay, forage, or roughage).

Hay is made of dried grass, legume or whole cereals. Grasses include among others timothy, ryegrasses, fescues. Legumes include among others clover, lucerne or alfalfa, peas, beans and vetches. Whole cereals include among others barley, maize (corn), oat, sorghum. Other forage crops include sugarcane, kales, rapes, and cabbages. Also root crops such as turnips, swedes, mangles, fodder beet, and sugar beet (including sugar beet pulp and beet molasses) are used to feed ruminants. Still further crops are tubers such as potatoes, cassava and sweet potato. Silage is an ensiled version of the fiber-rich fraction (e.g. from grasses, legumes or whole cereals) whereby material with a high water content is treated with a controlled anaerobic fermentation process (naturally-fermented or additive treated).

Concentrate is largely made up of cereals (such as barley including brewers grain and distillers grain, maize, wheat, sorghum), but also often contain protein-rich feed ingredients such as soybean, rapeseed, palm kernel, cotton seed and sunflower.

Cows may also be fed total mixed rations (TMR), where all the dietary components, e.g. forage, silage and concentrate, are mixed before serving.
As mentioned above a premix is an example of a feed additive which may comprise the active compounds according to the invention. It is understood that the compounds may be administered to the animal in different other forms. For example the compounds can also be included in a bolus that would be placed in the rumen and that would release a defined amount of the active compounds continuously in well defined dosages over a specific period of time.

The present invention further relates to a method for reducing the production of methane emanating from the digestive activities of ruminants and/or for improving ruminant animal performance, comprising orally administering a sufficient amount of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I) with the preferred embodiments described above.

Moreover, the invention further relates to a method as described above, wherein the compound of formula (I) is administered to the animal in combination with at least one additional active substance selected from the group consisting of diallyl disulfide, garlic oil, allyl isothiocyanate, deoxycholic acid,chenodeoxycholic acid and derivatives thereof.

The invention also relates to a method as described above, wherein the ruminant animal is selected from the group consisting of: cattle, goats, sheep, giraffes, American Bison, European bison, yaks, water buffalo, deer, camels, alpacas, llamas, wildebeest, antelope, pronghorn, and nilgai, and more preferably from the group consisting of: cattle, goats and sheep.

The invention also relates to a method as described above, wherein the amount of the at least one active compound as defined in formula (I) administered to the ruminant animal is from about 1 mg to about 10 g per kg feed, preferably from about 10 mg to about 1 g, more preferably from 50 mg to 500 mg compound per kg of feed.
The invention also relates to a method as described above, wherein the methane production in ruminants calculated in liters per kilogram of dry matter intake is reduced by at least 10 % when measured in metabolic chambers. Preferably, methane reduction is at least 15 %, more preferably, at least 20 %, even more preferably, at least 25 %, most preferably, at least 30 %. Alternative methane emission measurements may also be used like using a laser beam or for dairy ruminants, correlating methane production to the VFA profile in milk.

The invention also relates to a method as described above, wherein the ruminant feed conversion ratio is reduced by at least 1 % when measured in conventional performance trial. Preferably, the feed conversion ratio is reduced by at least 2 %, more preferably, by at least 2.5 %, even more preferably, by at least 3 %, most preferably, by at least 3.5 %.

The present invention is further described by the following examples which should not be construed as limiting the scope of the invention.
Examples

**Example 1: In vitro test for methane production**

A modified version of the "Hohenheim Forage value Test (HFT)" was used for testing the effect of specific compounds on the rumen functions mimicked by this in-vitro system.

**Principle:**

Feed is given into a syringe with a composition of rumen liquor and an appropriate mixture of buffers. The solution is incubated at 39 °C. After 8 hours the quantity (and composition) of methane produced is measured and put into a formula for conversion.

**Reagents:**

**Mass element solution:**
- 6.2 g potassium dihydrogen phosphate (KH$_2$PO$_4$)
- 0.6 g magnesium sulfate heptahydrate (MgSO$_4$ * 7H$_2$O)
- 9 ml concentrated phosphoric acid (1 mol/l)
  - dissolved in distilled water to 1 l (pH about 1.6)

**Buffer solution:**
- 35.0 g sodium hydrogen carbonate (NaHCO$_3$)
- 4.0 g ammonium hydrogen carbonate ((NH$_4$)HCO$_3$)
  - dissolved in distilled water to 1 l

**Trace element solution:**
- 13.2 g calcium chloride dihydrate (CaCl$_2$ * 2H$_2$O)
- 10.0 g manganese(II) chloride tetrahydrate (MnCl$_2$ * 4H$_2$O)
- 1.0 g cobalt(II) chloride hexahydrate (CoCl$_2$ * 6H$_2$O)
- 8.0 g iron(III) chloride (FeCl$_3$ * 6H$_2$O)
  - dissolved in distilled water to 100 ml
Sodium salt solution:
- 100 mg sodium salt
dissolved in distilled water to 100 ml

Reduction solution:
- first 3 ml sodium hydroxide (c = 1 mol/l), then 427.5 mg sodium sulfide hydrate (Na₂S * H₂O) are added to 71.25 ml H₂O
- solution must be prepared shortly before it is added to the medium solution

Procedure:

Sample weighing:
The feed stuff is sieved to 1mm - usually TMR (44 % concentrate, 6 % hay, 37 % maize silage and 13 % grass silage) - and weighed exactly into 64 syringes. 4 of these syringes are the substrate controls, which display the gas production without the effect of the tested compounds. 4 other syringes are positive control, in which bromoethane sulfonate has been added to 0.1 mM. When needed, 4 syringes contain a carrier control (if the test compounds need a carrier). The remaining syringes contain the test substances, by groups of 4 syringes.

Preparation of the medium solution:
The components are mixed in a Woulff bottle in following order:
- 711 ml water
- 0.18 ml trace element solution
- 355.5 ml buffer solution
- 355.5 ml mass element solution

The completed solution is warmed up to 39 °C followed by the addition of 1.83 ml sodium salt solution and the addition of reduction solution at 36 °C. The rumen liquor is added, when the indicator turns colourless.

Extraction of the rumen liquor:
750 ml of rumen liquor are added to approximately 1,400 ml of medium solution under continued agitation and CO₂-gassing.
Filling the syringes, incubation and determining gas volumes and VFA values:
The diluted rumen fluid (24 ml) is added to the glass syringe. The syringes are then
incubated for 8 hours at 39 °C under gentle agitation. After 8 hours, the volume of
gas produced is measured, and the percentage of methane in the gas phase is de-
termined by gas chromatography.

Results
The food fermented was artificial TMR (44 % concentrate, 6 % hay, 37 % maize si-
lage and 13 % grass silage). The compounds produced as described in examples 2
to 14 were added to the fermentation syringes to a concentration of 2 to 0.005 % of
dry matter (DM). The results are presented in the following table.

Table 3: Methane reduction effect resulting from the average of two experiments
with some compounds according to the present invention (an integer in the column
effect on methanogenesis change (%) means a reduction in methane produced
when compared to control; no value means that the concentration was not tested)

<table>
<thead>
<tr>
<th>Structure</th>
<th>Effect on methanogenesis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 % DM</td>
</tr>
<tr>
<td>HO-NO2</td>
<td>100</td>
</tr>
<tr>
<td>NO2-</td>
<td>10</td>
</tr>
<tr>
<td>NO2</td>
<td>85</td>
</tr>
<tr>
<td>Compound</td>
<td>99</td>
</tr>
</tbody>
</table>
Example 2: Comparative example: in vitro test for methane production.

The same in vitro assay as described in example 1 has been performed with a series of molecules, wherein the nitrooxy group has been replaced by different organic groups. Moreover, the inorganic salt Na NO₃ has also been tested. See results in Table 4. This data demonstrates that a significant methane reduction activity is only observed when the Nitrooxy group is present in the series.

Table 4: Methane reduction effect resulting from the average of two experiments with 3-nitrooxypropanol according to the present invention in comparison with similar compounds in which the nitrooxy group has been replaced. (An integer in the column effect on methanogenesis change (%) means a reduction in methane produced when compared to control; no value means that the concentration was not tested)

<table>
<thead>
<tr>
<th>Structure</th>
<th>effect on methanogenesis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 % DM</td>
</tr>
<tr>
<td>HO'—O—ONO₂</td>
<td>100</td>
</tr>
<tr>
<td>HO—O—NO₂</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Example 3: Synthesis of 3-Nitroxypropanol:

50.1 mmol 3-Bromopropanol dissolved in 100 ml acetonitrile and 125.25 mmol silver nitrate were added into a flask protected from light. This suspension was stirred for 21 hours at 70 °C. After cooling to room temperature the suspension was filtrated and concentrated in vacuo. The residue was dissolved in Water and extracted two times with TMBE. The organic phases were washed with water und brine, combined, dried over Na₂SO₄ and the solvent was removed in vacuo leaving 5.63 g.

The crude product was purified by flash chromatography on silica gel using heptane/ethyl acetate 2:1; Yield: 4.82 g (38.8 mmol, 77.4 %).

Example 4: Synthesis of 2-(Hydroxymethyl)-2-(nitrooxymethyl)-1,3-propanediol:
5 mmol 2-(Bromomethyl)-2-(hydroxymethyl)-1,3-propanediol dissolved in 20 ml acetonitrile and 15 mmol silver nitrate were added into a flask protected from light. This suspension was stirred for 24 hours at 70 °C. After cooling to room temperature the suspension was filtrated and the solvent was removed in vacuo leaving 3.05 g.

The crude product was purified by flash chromatography on silica gel using dichloromethane/methanol 50:1; Yield: 0.36 g (1.99 mmol, 40.2%).

Example 5: Synthesis of rac-4-Phenylbutane-1,2-diyl dinitrate:

7.5 mmol 4-Phenyl-1-buten dissolved in 40 ml acetonitrile, 20.3 mmol silver nitrate and 7.5 mmol lode were added into a flask protected from light. This suspension was stirred for 30 minutes at 25 °C and then for 16 hours at 79 °C. After cooling to room temperature the suspension was filtrated and washed with Ethyl acetate. The filtrate was extracted three times with water and washed brine, dried over Na2SO4 and the solvent was removed in vacuo leaving 1.92 g.

The crude product was purified by flash chromatography on silica gel using Hexane/Ethyl acetate 10:1; Yield: 0.52 g (2.03 mmol, 27%).

Example 6: Synthesis of N-Ethyl-3-nitrooxy-propionic sulfonyl amide:
In a flask 17 mmol 3-chloropropionic sulfonyl chloride were dissolved in 5 ml Tetrahydrofurane. 33.3 mmol Ethylamine were added over a period of 45 minutes. After that, the solvent was removed in vacuo. The residue was dissolved in water, extracted three times with ethyl acetate. The combined organic phases were washed with brine, dried over Na$_2$SO$_4$ and the solvent was removed in vacuo.

The residue was dissolved in 50 ml acetonitrile and 60 mmol silver nitrate were added into a flask protected from light. This suspension was stirred for 41 hours at 70 °C. After cooling to room temperature the suspension was filtrated and concentrated in vacuo. The residue was dissolved in dichloromethane and extracted with Water. The water phase was washed again with two times with dichloromethane. The combined organic phase was washed with water and brine, dried over Na$_2$SO$_4$ and the solvent was removed in vacuo; Yield: 3.05 g (14.5 mmol; 84.5 %).

**Example 7:** Synthesis of 3-Nitrooxy-propyl propionate:

9.1 mmol Propionyl chloride were dissolved in 10 ml TMBE and cooled to 3 °C. 8.25 mmol 3-Nitrooxypropanol and 9.1 mmol triethylamine in 5 ml TMBE were dropped over a period of 5min at 3 to 6 °C. After 2 hours and 30 minutes stirring
without cooling the reaction mixture were extracted with 1N HCl, twice with water, washed with brine, dried over Na₂SO₄ and the solvent was removed in vacuo leaving 1.35 g.

The crude product was purified by flash chromatography on silica gel using Hexane/Ethyl acetate 4:1; Yield: 1.14 g (6.4 mmol, 78.0%).

**Example 8**: Synthesis of 3-Nitrooxy-propyl benzoate:

\[
\text{PhCl} + \text{HOCH(O)ON} \rightarrow \text{PhOECH(O)ON}
\]

16.5 mmol 3-Nitrooxypropanol dissolved in 10 ml TMBE and 18.2 mmol Triethylamine were cooled to 3 °C. 18.2 mmol benzoylchloride in 5 ml TMBE were dropped over a period of 7 minutes at 3 to 6 °C. After 24 hours and 30 minutes stirring without cooling, the reaction mixture was extracted with sated NaHCO₃, water, 1N HCl, twice with water, washed with brine, dried over Na₂SO₄ and the solvent was removed in vacuo leaving 3.3 g.

The crude product was purified by flash chromatography on silica gel using a gradient of Hexane/Ethyl acetate from 1:0 to 2:1; Yield: 0.66 g (2.9 mmol, 17.7%).

**Example 9**: Synthesis of 3-Nitrooxy-propyl hexanoate:

\[
\text{CH(O)ONO} + \text{HOCH(O)ON} \rightarrow \text{CH(O)ON}
\]
20 mmol 3-Nitrooxypropanol dissolved in 10 ml Diethyl Ether and 20 mmol Triethyl-
amine were cooled to 0 °C. 18.2 mmol hexoylchlorid were dropped over a period of
5 minutes at 0 to 5°C. After 19 hours stirring without cooling, the reaction mixture
was extracted with 1N HCl, twice with water, washed with brine, dried over Na₂S₀₄
and the solvent was removed in vacuo leaving 3.1 g.

The crude product was purified by flash chromatography on silica gel using Hep-
tane/Ethyl acetate 4:1; Yield: 2.4 g (10.9 mmol, 60.0 %).

Example 10: Synthesis of 3-Nitrooxy-propyl 5-nitrooxy-hexanoate:

\[
\begin{align*}
\text{O}_2\text{NO} &\quad \text{O} \\
\text{Cl} &\quad \text{ONOO}_2 \\
181.58 \text{g/mol} &\quad 121.04 \text{g/mol} \\
\text{C}_6\text{H}_5\text{ClN}_0_4 &\quad \text{C}_3\text{H}_7\text{ON}_2\text{O}_4 \\
\end{align*}
\]

20 mmol 3-Nitrooxypropanol dissolved in 10 ml Diethyl Ether and 20 mmol Triethyl-
amine were cooled to 0 °C. 18.2 mmol 5-nitrooxypentoylchlorid were dropped over a
period of 5 min at 0 to 5°C. After stirring over night without cooling, the reaction mix-
ture was extracted with 1N HCl, twice with water, washed with brine, dried over Na₂S₀₄
and the solvent was removed in vacuo.

The crude product was purified by flash chromatography on silica gel using Hep-
tane/Ethyl acetate 4:1; Yield: 2.4 g (9.1 mmol, 50.0 %).

Example 11: Synthesis of Benzyl nitrate:

\[
\begin{align*}
\text{Ph} &\quad \text{NO}_2 \\
\text{Br} &\quad \text{AgNO}_3 \\
171.04 &\quad 153.14 \\
\text{C}_7\text{H}_7\text{Br} &\quad \text{C}_7\text{H}_7\text{NO}_3 \\
\end{align*}
\]
10 mmol Benzylbromide dissolved in 80 ml acetonitrile and 25 mmol silver nitrate were added into a flask protected from light. This suspension was stirred for 5 hours at 70 °C. After cooling to room temperature the suspension was filtrated and concentrated in vacuo. The residue was dissolved in dichloromethane and extracted with Water. The water phase was washed again with two times with dichloromethane. The combined organic phase was washed with water and brine, dried over Na$_2$SO$_4$ and the solvent was removed in vacuo; Yield: 1.55 g (10.1 mmol; 100 %).

**Example 12:** Synthesis of 1,3-bis-Nitrooxy-propane:

![Chemical Structure](image)

To a solution of 1,3-dibromopropane (2.00 g, 1.0 eq) in 20.0 mL of dry acetonitrile was added Silver Nitrate (3.70 g, 2.2 eq). The reaction mixture was heated at 70 °C for 2 hours in the dark. The resulting mixture was filtered off through celite and the filtrate was concentrated. The residue was dissolved into water (50.0 mL), extracted with dichloromethane (2 x 50.0 mL), dried over magnesium sulfate and solvents were evaporated under vacuum to afford 1.44 g of compound as a colorless liquid (Yield = 87 %).

**Example 13:** Synthesis of 1,4-bis-Nitrooxy-butane:

![Chemical Structure](image)

To a solution of 1,4-dibromobutane (2.00 g, 1.0 eq) in 20.0 mL of dry acetonitrile was added Silver Nitrate (3.50 g, 2.2 eq). The reaction mixture was heated at 70 °C for 2 hours in the dark. The resulting mixture was filtered off through celite and the
filtrate was concentrated. The residue was dissolved into water (50.0 mL), extracted with dichloromethane (2 x 50.0 mL) and dried over magnesium sulphate. Solvents were evaporated under vacuum to afford 1.49 g of compound as a colorless liquid (Yield = 89%).

**Example 14:** Synthesis of 1,5-bis-Nitrooxy-pentane

![Chemical structure]

To a solution of 1,5-dibromopentane (2.00 g, 1.0 eq) in 20.0 mL of dry acetonitrile was added Silver Nitrate (3.30 g, 2.2 eq). The reaction mixture was heated at 70 °C for 2 hours in the dark. The resulting mixture was filtered off through celite and the filtrate was concentrated. The residue was dissolved into water (50.0 mL), extracted with dichloromethane (2 x 50.0 mL) and dried over magnesium sulphate. Solvents were evaporated under vacuum to afford 1.38 g of compound as a colorless liquid (Yield = 82%).

**Example 15:** Synthesis of 5-Nitrooxy-pentanenitrile:

![Chemical structure]

To a solution of 5-bromovaleronitrile (4.00 g, 1.0 eq) in 40.0 mL of dry acetonitrile was added Silver Nitrate (4.60 g, 1.1 eq). The reaction mixture was heated at 70 °C for 2 hours in the dark. The resulting mixture was filtered off through celite and the filtrate was concentrated. The residue was dissolved into water (50.0 mL), extracted with dichloromethane (2 x 50.0 mL) and dried over magnesium sulphate. Solvents were evaporated under vacuum to afford 3.56 g of compound as a colorless liquid (Yield = 99%).
Example 16: Synthesis of Bis-(2-nitrooxyethyl) ether

16.05 mmol Bis (2-bromoethyl) ether dissolved in 30ml acetonitrile and 40.13 mmol silver nitrate were added into a flask protected from light. This suspension was stirred for 16h at 70°C. After cooling to room temperature the suspension was filtered and concentrated in vacuo. The residue was dissolved in Water and extracted two times with TMBE. The organic phases were washed with water und brine, combined, dried over Na2SO4 and the solvent was removed in vacuo leaving 3.06g. The crude product was filtrated over silica gel using heptane/ethyl acetate 1:1; Yield: 2.94g (15.0mmol, 93.4%).
Example 17: In vivo effect of 3-Nitrooxypropanol compared to ethyl-3-nitrooxypropionate:

Material and methods

10 sheep were cannulated in the rumen. The trial started one month after the surgical operation. There were 3 treatments: control, additive 1 and additive 2, both at a single dose. Additive 1 is ethyl-3-nitrooxypropionate, and additive 2 is 3-nitrooxypropanol of the present invention. The experimental design consisted of a 3 x 3 Latin square with 3 sheep per treatment in each period and 3 consecutive periods. Each period included 28 days of adaptation to the treatment plus two consecutive days of methane measurements in chambers and collection of rumen samples. Over the course of the adaptation phase, a medium term one day methane measurement was done at day 14. In addition, during days 22 and 23 samples of alfalfa hay and oats, placed in nylon bags, were incubated in the rumen of sheep to determine the dry matter ruminal degradation. During the two days of methane measurements in chambers (days 29 and 30) rumen contents samples were collected two hours after the morning feeding, sub-sampled and immediately frozen prior DNA extraction and determination of volatile fatty acids and ammonia nitrogen concentration. Experimental animals were randomly allocated in three sub-groups of 3 animals each and were randomly assigned one of the three treatments (control, additive 1 and additive 2). The 3 sub-groups started the adaptation to the diet with a gap of two days so they were in the same adaptation day prior methane measurement in the chambers. Animals were individually held in cages with constant access to fresh water. A diet consisting of alfalfa hay chopped at 15-20 cm and oats in a 60:40 ratio plus mineral-vitamin supplement was provided to the animals at approximately 1.1 times the energy maintenance level in two equal meals at 9:00 and 14:00 hours. Fresh matter intake was monitored daily for each animal throughout the trial. The additive was provided twice a day through the ruminal cannula at the same time as the feed. The corresponding amount to each additive (100 mg per animal and day for both additives) was pipetted into 10 grams of grounded oats and wrapped in cellulose paper immediately before it was placed in the rumen. Since the active
molecule is volatile the previously mentioned procedure was carried out in a cold room at 4°C.

**Methane measurement and samples collection**

A set of four methane chambers was used. On days 14, 29 and 30 animals were placed in the chambers for methane measurements. Each chamber measured 1.8 m wide × 1.8 m deep × 1.5 m tall. Chamber air temperature was maintained between 15 and 20°C. Within each chamber, the animals were individually restrained in the same cages as during adaptation. Interruptions occurred daily at 09:00 hours, when the chamber floor was cleaned, and the animals were fed. These interruptions had little impact on the daily methane emissions because fluxes were calculated three times per day and then averaged to derive the 23-h emission value. Airflow and concentration of methane was measured for the inflow and outflow ducts of each chamber. Air velocity was continuously monitored over the day in the exhaust duct for each chamber. The air stream in each of the 4 ducts (chambers 1, 2 and 3 and background) was sub-sampled, and methane concentration was measured continuously using a gas analyzer ADM MGA3000 (Spurling works, Herts, UK). It took 11 min to sequentially sample the airflow in all inflow and exhausts ducts in the chambers (3 min in chambers 1, 2, 3, 2 min for background). In summary, the flux of methane for each chamber was calculated for each measuring day from the difference of fresh-air inflow and chamber exhaust methane concentrations and mean air velocities.

**Rumen samples analysis**

Samples of rumen contents were freeze-dried and thoroughly mixed by physical disruption using a bead beater (Mini-bead Beater; BioSpec Products, Bartlesville, OK, USA) before DNA extraction, which was performed from approximately 50 mg of sample using the QIAamp® DNA Stool Mini Kit (Qiagen Ltd, West Sussex, UK) following the manufacturer's instructions with the modification that a higher temperature (95°C) was used for lysis incubation. DNA samples were used as templates for quantitative real-time PCR (qPCR) amplification. The abundance of total bacteria, total protozoa and total methanogenic archaea were quantified by Real Time - PCR
(qPCR). Different primer sets were used to amplify 16S rRNA gene-targeted total bacteria (Maeda et al., 2003), and 18S rRNA gene-targeted total protozoa (Sylvester et al. 2005). Primers designed for the detection of methanogenic archaea were targeted against the methyl coenzyme-M reductase (mcrA) gene (Denman et al., 2007). The amplifications mixture contained 11.5 µl 2X RT-PCR supermix Bio-Rad (Bio-Rad Laboratories Inc., Hercules, CA, USA), 0.4 µl of each primer and 0.5 µl of sample in a final volume of 23 µl. The amplification efficiency was evaluated for each pair of primers with the following program: a 5 min cycle at 95° C, 40 cycles at 95° C for 15s, 60° C for 30s, 72° C for 55s and, 75° C during 6s for fluorescent emission measures. The melting curve was built by increasing temperature from 55° C to 95° C and readings were taken every 5° C. Amplification of each target group was carried out with the following program: a 5 min cycle at 95° C, 40 cycles at 95° C for 15s, 15s at 60° C and 72° C for 45s (including the fluorescence emission measuring) and a melting curve with a set point temperature of 45° C and end temperature of 95° C. The absolute amount of bacteria, protozoa and methanogenic archaea, expressed as the number of DNA copies, was determined by using the plasmid pCR®4-TOPO (Invitrogen™, Carlsbad, CA, USA) as standard. The PCR product obtained using the respective set of primers was purified and then cloned into pCR® 4-TOPO® plasmid (Invitrogen™, Carlsbad, CA, USA) to produce recombinant plasmids. A single colony, verified for the expected insert using PCR, was grown in solid media with antibiotics and X-gal overnight. Afterwards, a screening of transformed E. coli colonies was done and some of the positive ones were randomly selected. After checking the presence of the inserted fragment in the colonies by PCR, massive culture of positive colonies was done in liquid media overnight. Plasmids belonging to these cultures were extracted using the Pure Link™ Miniprep kit (Invitrogen™, Carlsbad, CA, USA) and then sequenced to verify the presence of the fragment inserted. The number of 16S rRNA gene copies present in the plasmid extracts was calculated using the plasmid DNA concentration and the molecular mass of the vector with the insert. The concentrated plasmid was serially diluted (10-fold) to provide a range of 10⁸ to 10² copies to generate a standard curve.

A relative abundance quantification was used for methanogenic archaea and protozoa as described by Denman and McSweeny (2006) using the 16sRNA as refer-
ence gene. Volatile fatty acids were analysed by gas chromatography and ammonia N concentration by colorimetry following the protocols established in our laboratory (Martin-Garcia et al., 2004).

### Rumen degradability

Three grams of 2 mm ground feed were placed in 5 cm x 10 cm nylon bags with a pore size of 50 μm (#R510 Ankom in situ bags, Macedon NY). The two ingredients used in the animals’ diets were tested: oats and alfalfa hay. Bags with oats were incubated in the rumen for 24 hours, while those with alfalfa hay for 48 hours. The incubations times were chosen based on average residence times in the rumen of different feedstuffs. On days 22 and 23 two bags per feed and animal and period were. Bags were placed in the rumen immediately before the morning feeding. At 24 or 48 hours they were taken out of the rumen, washed with cold water and frozen at -20°C. At the end of every period the frozen bags were washed in a washing machine using a short cold water program including two bags per feed that had not been incubated in the rumen to account for solubility. After washing, the bags were placed in the oven at 60°C for 48 hours. Rumen degradability (%) was calculated as the loss of dry matter over the incubation time.

### Experimental animals care

All management and experimental procedures to the sheep were carried out by trained personnel in strict accordance with the Spanish guidelines (Act No. 1201/2005 of 10 October 2005) for experimental animal protection. The temperature, humidity and air turn out in chambers were carefully monitored considering the animal welfare conditions. CO2 concentration was also continuously monitored in order to keep it within the limits that ensured a good air quality and renovation rate. Animals didn’t show any stressed behaviour while they were allocated in chambers.

### Statistical analysis

Individual methane emissions, VFA profiles, ratio of acetate to propionate, ammonia N concentration, $\log_{10}$ transformations of concentration of total bacteria, total protozoa and methanogenic archaea and the relative abundance were analyzed for effect
of including the additive. The standard error of the mean (SEM) was computed for each analysis. Means were further compared using a least significant difference (LSD) test.

5 Results

Dry matter intake was not affected (P>0.05) by the treatment and only slight reduction in intakes were observed when the animals were introduced in the methane chambers on days 14 and 30.

As described for intakes, the body weight (as an average of weights recorded prior and after chamber measurements) was not different (P>0.05) among treatments (Table 5). Methane emissions, expressed as litres per kg of fresh matter intake, were significantly (P=0.020) reduced on day 14 when both additives were incorporated in the diet. The reduction observed against the control was 14 % and 23 %, respectively, for additives 1 and 2. When methane emissions were recorded two weeks later, on days 29 and 30, there was still a numerically reduction, although it did not reach the statistical significance (P=0.061 and 0.183 for days 29 and 30, respectively). If the measurements recorded during the last two consecutive days are pooled together the effect of the addition shows a similar tendency (P=0.092) as the values considered separately.

Table 5. Effect of the addition of additives 1 and 2 on body weights, intakes and methane emissions by sheep measured on days 14, 29 and 30 after commencing the treatment.

<table>
<thead>
<tr>
<th>Time</th>
<th>Item</th>
<th>Control</th>
<th>Additive 1</th>
<th>Additive 2</th>
<th>SEM</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>day 14</td>
<td>intake, kg/day</td>
<td>0.819</td>
<td>0.849</td>
<td>0.867</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH4 l/day</td>
<td>24.6</td>
<td>21.9</td>
<td>20.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CH4 l/kg intake</td>
<td>29.9</td>
<td>25.6</td>
<td>22.5</td>
<td>2.31</td>
<td>0.020</td>
</tr>
</tbody>
</table>
### Table 6. Effect of the addition of additive 1 and 2 on volatile fatty acid profile (mol/100 mol), ammonia N concentration (mg/100 ml) and dry matter degradation (DMD, %) of oats (24 hours) and alfalfa hay (48 hours) in the rumen of sheep.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Additive 1</th>
<th>Additive 2</th>
<th>SEM</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetate</td>
<td>69.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>67.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>64.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.742</td>
<td>0.007</td>
</tr>
<tr>
<td>Propionate</td>
<td>14.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>16.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.030</td>
<td>0.004</td>
</tr>
<tr>
<td>Butirate</td>
<td>2.08</td>
<td>2.05</td>
<td>2.11</td>
<td>0.818</td>
<td>0.353</td>
</tr>
<tr>
<td>iso-butirate</td>
<td>11.2</td>
<td>10.1</td>
<td>12.3</td>
<td>0.201</td>
<td>0.995</td>
</tr>
<tr>
<td>Valerate</td>
<td>1.91</td>
<td>1.94</td>
<td>1.82</td>
<td>0.194</td>
<td>0.100</td>
</tr>
<tr>
<td>iso-valerate</td>
<td>1.47</td>
<td>1.79</td>
<td>1.82</td>
<td>0.281</td>
<td>0.908</td>
</tr>
<tr>
<td>Total</td>
<td>57.4</td>
<td>58.2</td>
<td>57.1</td>
<td>5.193</td>
<td>0.995</td>
</tr>
<tr>
<td>C2/C3</td>
<td>4.91&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.262</td>
<td>0.002</td>
</tr>
<tr>
<td>N-NHs</td>
<td>100.1</td>
<td>97.3</td>
<td>104.1</td>
<td>9.157</td>
<td>0.924</td>
</tr>
</tbody>
</table>
DMD alfalfa hay 78.6 78.3 78.8 1.22 0.725
DMD oats 74.2 74.0 70.6 2.02 0.167

Values in a row not sharing a common superscript letters significantly differ, P<0.005.

SEM: Standard Error of the Means

The study of the rumen fermentation parameters from rumen samples collected on days 29 and 30 showed a shift in the fermentation pathways (Table 5) towards a more propionate type profile in the rumen of animals receiving both additives in comparison to the control. As a consequence, in both treatments the acetate to propionate ratio was significantly (P=0.002) reduced. The concentration of ammonia was similar among treatments and within the range expected for the diet supplied to the animals.

The in sacco degradation study on days 22\textsuperscript{nd} and 23\textsuperscript{rd} showed no effect of the additive treatment on the rumen degradability of both alfalfa hay and oats.

Table 7. Effect of the addition of additives 1 and 2 on the concentration (log copy gene numbers/g fresh matter) of total bacteria (16S rRNA), protozoa (18S rRNA) and methanogenic archaea (mcrA gene) in the rumen of sheep. The relative abundance (\textit{ACt}) in relation to total bacteria is also shown for protozoa and methanogens.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Additive 1</th>
<th>Additive 2</th>
<th>Error</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total bacteria</td>
<td>$7.45 \times 10^{10}$</td>
<td>$9.08 \times 10^{10}$</td>
<td>$9.74 \times 10^{10}$</td>
<td>0.123</td>
<td>0.607</td>
</tr>
<tr>
<td>log 10</td>
<td>10.8</td>
<td>10.9</td>
<td>11.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total protozoa</td>
<td>$2.84 \times 10^{10}$</td>
<td>$1.87 \times 10^{10}$</td>
<td>$2.51 \times 10^{10}$</td>
<td>0.212</td>
<td>0.702</td>
</tr>
<tr>
<td>log 10</td>
<td>10.4</td>
<td>10.2</td>
<td>10.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACt</td>
<td>1.65</td>
<td>1.58</td>
<td>1.55</td>
<td>0.267</td>
<td>0.984</td>
</tr>
</tbody>
</table>
Total and relative concentration of the analysed microbial groups in the rumen showed no difference (P>0.05) among treatments. When the abundance of both protozoa and methanogenic archaea were expressed relative to total bacteria the same lack of effect was observed.

**Conclusions**

The use of both additives resulted in a significant reduction of methane production and, according to the VFA profiles, a shift in the metabolic pathways involved in H₂ transferring was promoted by additives as well. The objective of this trial was to confirm whether the treatment of animals for a month showed a persistence of the results observed over two weeks treatment. This is essential when assessing the suitability of the practical use of a feed additive. In this study both additives showed effect over a month treatment in methane emissions that was further confirmed by a shift in the fermentation pattern.

On the other hand, a change in the fermentation pattern might be not only due to a reduction in methane production but also to a lower fibre degradation which, in turn, would produce less acetate and therefore lowered acetate to propionate ratio. In order to rule out this occurring, a rumen degradability assessment was carried out by incubating nylon bags with both oats and alfalfa hay in the rumen of the animals. The results showed no such effect on dry matter degradation which is also supported by the same bacterial and protozoa biomass recorded in animals receiving the additives compared to those with no treatment.

*Example 18: In vivo effect of 3-Nitrooxypropanol in dairy cows*
Material and Methods

Animals: Six rumen fistulated lactating Holstein X Friesian dairy cows of second or
greater parity and weighing from 550 to 800 kg were used for the study. Cows were
in mid lactation at the start of the study.

Experimental diets: A single total mixed ration (TMR) diet was provided to all cows
throughout the study. Cows were fed ad libitum (5% refusals) for the duration of the
trial.

Experimental design: Beginning in mid lactation (with milk yields of 30 litres or
more), the six cows were randomly assigned to one of the three supplement treat-
ments in a 3 x 3 Latin Square design (Table 8). Treatment periods were 5 weeks in
duration.

Table 8. Experimental design

<table>
<thead>
<tr>
<th>Cow</th>
<th>Pair 1</th>
<th>Pair 2</th>
<th>Pair 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Square 1</td>
<td></td>
<td>Square 2</td>
</tr>
<tr>
<td></td>
<td>Cow 888</td>
<td>Cow 989</td>
<td>Cow 973</td>
</tr>
<tr>
<td>Period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Diets: 1- Control
2 - 3-Nitrooxypropanol (500 mg/day)
3 - 3-Nitrooxypropanol (2500 mg/day)

Dosing of 3-Nitrooxypropanol or placebo: The doses of 3-Nitrooxypropanol or
placebo was administered to the animals via the rumen cannula at feeding time in
the morning and evening.
Period Design: As only two cows can be housed in the indirect calorimeters at any one time cows were run in pairs staggered by one week. At the end of week 4 animals were moved to the indirect calorimeters and held in individual tie stalls where four complete 24 hr measurements of respiratory exchange (methane and carbon dioxide production and oxygen consumption) were obtained (Cammell et al., 2000).

Results

Feed Intake: There was no significant effect of the product (3-Nitrooxypropanol) on daily dry matter intake (DMI) (see table 9).

Methane Production: Methane production (litres/d) and methane yield (litres/kg DMI) were significantly reduced by the 3-Nitrooxypropanol. Methane production was 93 and 90% of control values when the 500 and 2500 mg/d doses were given, respectively (see table 9). As regards methane yield, the corresponding values were 96 and 93% of control methane yield, respectively, for the low and high doses.

Table 9. Effects of DSM product fed at two doses.

<table>
<thead>
<tr>
<th>Daily dose, mg/d</th>
<th>0</th>
<th>500</th>
<th>2500</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg/d</td>
<td>18.9</td>
<td>18.8</td>
<td>18.5</td>
<td>0.7</td>
</tr>
<tr>
<td>CH₄, L/d</td>
<td>594</td>
<td>555</td>
<td>536</td>
<td>15.3</td>
</tr>
<tr>
<td>CH₄, g/d</td>
<td>425</td>
<td>398</td>
<td>384</td>
<td>11.0</td>
</tr>
<tr>
<td>CH₄, L/kg DMI</td>
<td>31.3</td>
<td>29.9</td>
<td>29.2</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Large variations were observed between animals some showing more response that some others. These results show the potential of the compounds of the present invention in reducing methane production in dairy cows, and shed light on further improving the feeding regimen.
Claims

1. Use of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I)

\[ \text{formula (I)} \]

\[ \text{O}_2\text{N}^\gamma \]

wherein \( \gamma \) is an organic molecule of the following composition: \( \text{C}_a\text{H}_b\text{O}_d\text{N}_e\text{S}_g \), wherein

- \( a \) is comprised between 1 and 25,
- \( b \) is comprised between 2 and 51,
- \( d \) is comprised between 0 and 8,
- \( e \) is comprised between 0 and 5,
- \( g \) is comprised between 0 and 3,

as an active compound in animal feeding for reducing the formation of methane emanating from the digestive activities of ruminants, and/or for improving ruminant performance,

wherin nitrooxy alkanoic acid, and/or derivatives thereof as defined by the formula (II) are excluded,

\[ \text{formula (II)} \]

\[ \text{O}_2\text{N}^\gamma \]

\[ \text{O}^\gamma \]

\[ \text{O}^\gamma \]

\[ \text{R}_1 \]

\[ \text{R}_2 \]

\[ \text{R}_3 \]

wherein

- \( u \) is comprised between 0 and 23 and, wherein if \( u \neq 0 \), the carbon chain is a linear, a cyclic, or branched linear or cyclic aliphatic carbon chain which may be mono- or polyunsaturated and in any isomeric form,
Z is independently 0, NH, or N-R3, wherein if R1 ≠ H, Z-R1 - represents an ester or a secondary amide derivative,

R1 is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 10 carbon atoms,

R2 is independently, hydrogen or a saturated straight or branched chain of an alkyl or alkenyl group containing 1 to 23 carbon atoms, and

R3 is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 10 carbon atoms.

2. Use according to claim 1, wherein

   a is comprised between 1 and 10,
   b is comprised between 2 and 21,
   d is comprised between 0 and 6,
   e is comprised between 0 and 3,
   g is comprised between 0 and 1.

3. Use according to claim 1, wherein the at least one organic molecule of formula (I), is a compound of formula (III),

\[
\begin{align*}
O_2N & \quad (I) \\
\begin{array}{c}
R4 \\
\end{array} & \quad (III)
\end{align*}
\]

wherein

   n is comprised between 0 and 12, preferably comprised between 0 and 6 and, wherein, if n ≠ 0, the carbon chain is a linear, a cyclic, or branched aliphatic carbon chain which may be non substituted or substituted with up to 3 hydroxyl-, alkoxy-, amino-, alkylamino-, dialkylamino- or nitrooxy groups, or an alkenyl, or alkynyl carbon chain mono- or polyunsaturated and in any isomeric form,
R4 is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 12, preferably 1 to 6 carbon atoms,

X is hydrogen, R5, R5≡N, -OR5, -OCOR5, -NR5R6, -ON02, -COOR5, -CONR5R6, -NHS02R5, or -S02NHR5,

R5 and R6 are independently, hydrogen, C1-C12 straight, branched or cyclic alkyl chain, non substituted or substituted with up to 3 hydroxyl-, alkoxy-, amino-, alkylamino-, dialkylamino- or nitrooxy groups, alkenyl, or alkylnyl carbon chain which may be mono or polyunsaturated, and in any isomeric form.

4. Use according to any of claims 1 to 3, wherein the at least one organic molecule of formula (I), or a salt thereof is selected from 3-Nitrooxypropanol, racemate-4-Phenylbutane-1,2-diyl dinitrate, 2-(Hydroxymethyl)-2-(nitrooxymethyl)-l,3-propanediol, N-Ethyl-3-nitrooxy-propionic sulfonyl amide, 5-Nitrooxy-pentanenitrile, 5-Nitrooxy-pentane, 3-Nitrooxy-propyl propionate, 1,3-bis-Nitrooxypropane, 1,4-bis-Nitrooxybutane, 1,5-bis-Nitrooxypentane, 3-Nitrooxy-propyl benzoate, 3-Nitrooxy-propyl hexanoate, 3-Nitrooxy-propyl 5-nitrooxy-hexanoate, Benzylnitrare, isosorbid-dinitrate, and N-[2-(Nitrooxy)ethyl]-3-pyridinecarboxamide, 2-Nitro-5-nitrooxymethyl-furan, and Bis-(2-nitrooxyethyl) ether.

5. Use according to any of claims 1 to 4, wherein the at least one organic molecule of formula (I), or a salt thereof is selected from 3-Nitrooxypropanol, 5-Nitrooxy-pentanenitrile, 5-Nitrooxy-pentane, 3-Nitrooxy-propyl propionate, 1,3-bis-Nitrooxypropane, 1,4-bis-Nitrooxybutane, 1,5-bis-Nitrooxypentane, 3-Nitrooxy-propyl benzoate, 3-Nitrooxy-propyl hexanoate, 3-Nitrooxy-propyl 5-nitrooxy-hexanoate, isosorbid-dinitrate, and N-[2-(Nitrooxy)ethyl]-3-pyridinecarboxamide, and Bis-(2-nitrooxyethyl) ether.

6. Use according to any of claims 1 to 5, wherein the at least one organic molecule of formula (I), is a mixture of 3-nitrooxy propanol and 1,3-bis-nitrooxypropane.
7. Use according to any of claims 1 to 6, wherein the at least one organic molecule of formula (I), or a salt thereof is combined with at least one additional active substance selected from the group consisting of diallyl disulfide, garlic oil, allyl isothiocyanate, deoxycholic acid, chenodeoxycholic acid and derivatives thereof.

8. Use according to any of claims 1 to 7, wherein the ruminant animal is selected from the group consisting of: cattle, goats, sheep, giraffes, American Bison, European bison, yaks, water buffalo, deer, camels, alpacas, llamas, wildebeest, antelope, pronghorn, and nilgai.

9. Use according to any of claims 1 to 8, wherein the methane production in ruminants calculated in liters per kilogram of dry matter intake is reduced by at least 10 % when measured in metabolic chambers.

10. Use according to any of claims 1 to 9, wherein the amount of the at least one active compound as defined in formula (I) administered to the ruminant animal is from 1 mg to 10 g per kg feed.

11. A feed composition or feed additive comprising at least one organic molecule of formula (I) according to any of claims 1 to 6.

12. The composition of claim 11 which is a mineral premix, a vitamin premix, or a premix including vitamins and minerals or a bolus.

13. A method for reducing the production of methane emanating from the digestive activities of ruminants and/or for improving ruminant animal performance comprising orally administering a sufficient amount of at least one organic molecule substituted at any position with at least one nitrooxy group, or a salt thereof as defined by formula (I) to the animal,
wherein \( Y \) is an organic molecule of the following composition: \( C_aH_bO_dN_eS_g \).  

wherein  
\[ a \] is comprised between 1 and 25,  
\[ b \] is comprised between 2 and 51,  
\[ d \] is comprised between 0 and 8,  
\[ e \] is comprised between 0 and 5,  
\[ g \] is comprised between 0 and 3,  

wherein nitrooxy alkanoic acid, and/or derivative thereof as defined by the formula (II) are excluded,

\[
\begin{align*}
&\text{O}_2\text{N} \quad \text{O} \\
&\quad \text{R}_2 \quad \text{Z} \quad \text{R}_1 \\
&\quad \text{formula (II)}
\end{align*}
\]

wherein  
\[ u \] is comprised between 0 and 23 and, wherein if \( u \neq 0 \), the carbon chain  
is a linear, a cyclic, or branched linear or cyclic aliphatic carbon chain  
which may be mono- or polyunsaturated and in any isomeric form,  
\[ Z \] is independently 0, NH, or N-R3, wherein if \( R \neq H \), Z-R1 represents an ester or a secondary amide derivative,  
\[ R \] is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 10 carbon atoms,  
\[ R \] is independently, hydrogen or a saturated straight or branched chain of an alkyl or alkenyl group containing 1 to 23 carbon atoms, and  
\[ R \] is independently, hydrogen or a saturated straight, cyclic or branched chain of an alkyl or alkenyl group containing 1 to 10 carbon atoms.
14. A method according to claim 13, wherein the at least one organic molecule is administered to the animal in combination with at least one additional active substance selected from the group consisting of diallyl disulfide, garlic oil, allyl isothiocyanate, deoxycholic acid, chenodeoxycholic acid and derivatives thereof.

15. A method according to claims 13 or 14, wherein the ruminant animal is selected from the group consisting of: cattle, goats, sheep, giraffes, American Bison, European bison, yaks, water buffalo, deer, camels, alpacas, llamas, wildebeest, antelope, pronghorn, and nilgai.

16. A method according to any of claims 13 to 15, wherein the amount of the at least one organic molecule as defined in formula (I) administered to the ruminant animal is from 1 mg to 10 g per kg feed.

17. A method according to any of claims 13 to 16, wherein the methane production in ruminants calculated in liters per kilogram of dry matter intake is reduced by at least 10% when measured in metabolic chambers.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. A23K1/16 A23K1/18

ADD.

According to International Patent Classification (IPC) and both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

A23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, BIOSIS, COMPRENDIX, FSTA, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>U. FAGERHOLM ET AL: &quot;Pre-cl inical pharmacoki neti cs of the cycl o oxygenei niti ng nitr c oxii de donor (CINOD) AZD3582&quot;, JOURNAL OF PHARMACY AND PHARMACOLOGY, vol. 57, no. 5, 1 May 2005 (2005-05-01) , pages 587-598, XP055007683, ISSN: 0022-3573, DOI: 10.1211/00223570506028 page 590, right-hand column, paragraph 1; figure 1 ----- */- .</td>
<td>11, 12</td>
</tr>
</tbody>
</table>

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  * "A" document defining the general state of the art which is not considered to be of particular relevance
  * "E" earlier application or patent but published on or after the international filing date
  * "L" document which may throw doubts on priority claim(s) one of which is cited to establish the publication date of another citation or other special reason (as specified)
  * "O" document referring to an oral disclosure, use, exhibition or other means
  * "P" document published prior to the international filing date but later than the priority date claimed

**Date of the actual completion of the international search**

1 June 2012

**Date of mailing of the international search report**

11/06/2012

**Name and mailing address of the ISA**

Saettel, Damien

European Patent Office, P.B. 5818 Patentlaan 2

NL - 2280 HV Rijswijk

Tel. (+31-70) 340-2040,

Fax: (+31-70) 340-3016

**Authorized officer**


Form PCT/ISA/210 (second sheet) (April 2005)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>EP 0 685 169 AI (SNOW BRAND SEED CO LTD [JP]; TAKAHASHI JUNICHI [JP])</td>
<td>1-17</td>
</tr>
<tr>
<td>A</td>
<td>GB 1 268 952 A (MERCK &amp; CO INC [US])</td>
<td>1-17</td>
</tr>
<tr>
<td>A</td>
<td>01/26482 AI (DCV INC [US])</td>
<td>1-17</td>
</tr>
<tr>
<td>Patent document cited in search report</td>
<td>Publication date</td>
<td>Patent family member(s)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-----------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td>WO 2010072584 A l</td>
<td>01-07-2010</td>
<td>NONE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AU 2044395 A 14-12 - 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2150892 AI 03-12 - 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 69520304 DI 19-04 - 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 69520304 T2 20-09 - 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DK 685169 T3 14-05 - 2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 0685169 AI 06-12 - 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 7322828 A 12-12 - 1995</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NZ 272268 A 25-06 - 1996</td>
</tr>
<tr>
<td>GB 1268952 A</td>
<td>29-03-1972</td>
<td>CA 963311 AI 25-02 - 1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CH 565514 A5 29-08 - 1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 1931413 AI 06-05 - 1970</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 1966491 B2 08-06 - 1978</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DE 2100148 AI 16-09 - 1971</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FR 2011970 AI 13-03 - 1970</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1268952 A 29-03 - 1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1270229 A 12-04 - 1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GB 1270230 A 12-04 - 1972</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 50015710 B 06-06 - 1975</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NL 6908567 A 23-12 - 1969</td>
</tr>
<tr>
<td></td>
<td></td>
<td>US 3608087 A 21-09 - 1971</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CA 2382732 AI 19-04-2001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP 1231844 AI 21-08-2002</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JP 2003529333 A 07-10-2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NZ 518372 A 31-10-2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>W0 0126482 AI 19-04-2001</td>
</tr>
</tbody>
</table>