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(54) **NOVEL FATTY ACID ANALOGOUS**

NEUE FETTSÄUREANALOGA

NOUVEAUX ANALOGUES D'ACIDES GRAS

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(73) Proprietor: **Thia Medica AS**
5018 Bergen (NO)

(72) Inventors:
- **BERGE, Rolf**
  5152 Bones (NO)
- **SYDNES, Leiv, K.**
  5046 Radal (NO)
- **SONGSTAD, Jon**
  5019 Bergen (NO)

(74) Representative: **Plougmann & Vingtoft A/S**
Sundkrogsgade 9,
P.O. Box 831
2100 Copenhagen (DK)

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Remarks:

The file contains technical information submitted after the application was filed and not included in this specification

Description

FIELD OF THE INVENTION

[0001] The present invention relates to novel fatty acid analogues. Further, the invention relates to the use of the novel fatty acid analogues for the treatment and/or prevention of syndrome X, obesity, hypertension, fatty liver, diabetes, hyperglycaemia, hyperinsulinemia and stenosis. The invention also relates to processes for the preparation of the novel fatty acid analogues.

BACKGROUND OF THE INVENTION

[0002] EP 345.038 describes the use of non-β-oxidizable fatty acid analogues of the formula;

$$\text{Alkyl-X-CH}_2\text{COOR}$$

wherein the alkyl is a saturated or unsaturated hydrocarbon chain of 8 to 22 carbon atoms, X represents a O, S, SO or SO2, and R is hydrogen or a C1 - C4 alkyl group, for the treatment of hyperlipaemic conditions and for the reducing the concentration of cholesterol and triglycerides in the blood of mammals.

[0003] WO-97/03663 describes alkyl-S-CH_2COOR and alkyl-Se-CH_2COOR for the inhibition of the oxidative modification of LDL. Further, this application describes the use of the selenium-compound for the treatment of hyperlipaemic condition and for reducing the concentration of cholesterol and trigylcerides.

[0004] The PCT publications WO 99/58121, WO 99/58122 and WO 99/58123 describe fatty acid analogues of the formula (I)

$$CH_3\text{-}[CH_2]_m\text{-}[x_i\text{-}CH_2]_n\text{-}COOR$$

- wherein *n* is an integer from 1 to 12, and
- wherein *m* is an integer from 0 to 23, and
- wherein *i* is an odd number which indicates the position relative to COOR, and
- wherein X_i independent of each other are selected from the group comprising O, S, SO, SO_2, Se and CH_2, and
- wherein R represents hydrogen or C_1-C_4 alkyl,
- with the proviso that at least one of the X_i is not CH_2,

or a salt, prodrug or complex thereof.

[0005] This formula comprises one or several X groups (preferably selenium and sulphur) in positions 3, 5, 7, 9, etc.

[0006] Further, these PCT publications describe several medicinal and nutritional applications.

[0007] WO99/58121 describes the use of the fatty acid analogues the treatment and/or prevention of obesity, hypertension, fatty liver and the multi metabolic syndrome termed «metabolic syndrome» or Syndrome X. Further, this application describes a method for the treatment or prevention of an obese or overweight condition, and a method for producing weigh loss or a reduction of the fat mass in a human or non-human animal. The application also describes a nutritional composition effective to reduce, or to prevent an increase in, the total body weight or the total body fat mass in a human or non-human animal, and also a method for the modification of the fat distribution and content of animals in order to improve the quality of the meat, or product such as milk and eggs.

[0008] WO 99/58122 describes use of fatty acid analogues for the treatment and/or prevention of diabetes (both type I and II), and a method for the treatment or prevention of hyperglycaemia, hyperinsulinemia and reduced sensitivity to insulin. A nutritional composition effective to reduce, or to prevent an increase in the concentration of glucose in the blood of a human or non-human animal is also disclosed, as is a method for reducing the concentration of glucose in the blood of a human or non-human animal.

[0009] WO 99/58123 describes the use of the fatty acid analogues for the treatment and/or prevention of primary and/or secondary stenosis, and/or a disease caused by procedural vascular trauma and/or pathological proliferation of smooth muscle cells, and/or an increased level of plasma homocystein.

[0010] Due to the X-atom (most preferable sulphur or selenium) that is substituted in the carbon chain of the above given fatty acid analogues, these compounds will not be β-oxidized in the mitochondria beyond this position. Thus, the degradation of these molecules must start from the methyl end of the fatty acid, and this is a rather slow metabolic process. The catabolism of these fatty acid analogues includes ω-oxidation and chain shortening of the dicarboxylic acid by peroxisomes. Enzymes in the endoplasmic reticulum will ω-hydroxylate and further oxidise the hydroxylated fatty acid to a dicarboxylic acid.

[0011] This acid may then be chain shortened by β-oxidation in the peroxisomes. Studies in rats have shown that 50% of the analogue TTA was excreted in the urine as short sulfoxy dicarboxylic acids within 24 hours of administration. In similar experiments it has been found that a desaturated product of TTA is formed in vivo. This is due to the microsomal enzyme Δ^9-desaturase which inserts a double bond in the 9-position of saturated fatty acids.

[0012] It is anticipated that this desaturated product has similar effects, and/or mediates the biological effects of the saturated fatty acid analogues. It is also likely that the biological effects of fatty acid analogues may be potentiated by slowing down their catabolism. This can be done by inserting double and/or triple bonds near the methyl end of the fatty acids, and/or by incorporating alkyl groups or halogens in this part of the molecule. Such molecules, i.e. the compounds in accordance with the present invention, will not be substrates for the relevant microsomal enzymes.

OBESITY, AND RELATED DISEASES

[0013] Obesity is a chronic disease that is highly prevalent in modern society and is associated not only with a social stigma, but also with decreased life span and numerous medical problems, including adverse psychological development, reproductive disorders such as polycystic ovarian disease, dermatological disorders such as infections, varicose veins, Acanthosis nigricans, and eczema, exercise intolerance, diabetes mellitus, insulin resistance, hypertension, hypercholesterolemia, cholelithiasis, osteoarthritis, orthopedic injury, thromboembolic disease, cancer, and coronary heart disease.

[0014] It is therefore an object of the present invention to provide a treatment regimen that is useful in returning the body weight of obese subjects toward a normal, ideal body weight.

[0015] It is another object to provide a therapy for obesity that results in maintenance of the lowered body weight for an extended period of time. Further, it is an object to reduce or inhibit the weight gain normally induced by fat rich diets.

[0016] It is yet another object to prevent obesity and, once treatment has begun, to arrest progression or prevent the onset of diseases that are the consequence of, or secondary to, the obesity, such as hypertension and fatty liver. These and other objects will be apparent to those of ordinary skill in the art.

[0017] The obesity herein may be due to any cause, whether genetic or environmental. Examples of disorders that may result in obesity or be the cause of obesity include overeating and bulimia, polycystic ovarian disease, craniopharyngioma, the Prader-Willi Syndrome, Frohlich's syndrome, Type II diabetics, GH-deficient subjects, normal variant short stature, Turner's syndrome, and other pathological conditions showing reduced metabolic activity.

[0018] It is also an object of the present invention to provide a treatment regimen that is useful in lowering the blood pressure.

[0019] Further, it is an object of the present invention to provide a treatment regimen that is useful in lowering the concentration of triacylglycerols in the liver. It is anticipated that such a regimen will provide an inhibiting effect on the development of a fatty liver condition, and also be suited as a method for the treatment of the manifested disease.

[0020] The compounds of the present invention activate the β-oxidation, and also reduce the concentration of triglycerieds in the liver.

[0021] The term "metabolic syndrome" is used to describe a multi-metabolic syndrome which is *inter alia* characterized by hyperinsulinemia, insulin resistance, obesity, glucose intolerance, Type 2 diabetes mellitus, dyslipidemia or hypertension.

[0022] As indicated above it is anticipated that the compounds of the present invention will provide a positive effect on all the conditions mentioned above, i.e. by regulating both the glucose and lipid homeostasis, and thus it is anticipated that the compounds of the present invention will be suitable agents for the regulation of the above defined metabolic disease (sometimes called syndrome X).

DIABETES

[0023] There are two major forms of diabetes mellitus. One is type I diabetes, which is also known as insulin-dependent diabetes mellitus (IDDM), and the other is type II diabetes, which is also known as noninsulin-dependent diabetes mellitus (NIDDM). Most patients with IDDM have a common pathological picture; the nearly total disappearance of insulin-producing pancreatic beta cells which results in hyperglycemia.

[0024] Considerable evidence has been accumulated showing that most IDDM is the consequence of progressive beta-cell destruction during an asymptomatic period often extending over many years. The prediabetic period can be recognized by the detection of circulating islet-cell autoantibodies and insulin autoantibodies.

[0025] There is a need for a compound which would be nontoxic and have no side effects but which would prevent clinical IDDM and NIDDM.

[0026] Type I diabetes: severe diabetes mellitus, usually of abrupt onset prior to maturity, characterized by low plasma insulin levels, polydipsia, polyuria, increased appetite, weight loss and episodic ketoacidosis; also referred to as IDDM.

[0027] Type II diabetes: an often mild form of diabetes mellitus, often of gradual onset, usually in adults, characterized by normal to high absolute plasma insulin levels which are relatively low in relation to plasma glucose levels; also referred to as NIDDM.

[0028] Type I and II diabetes are in accordance with an etiologic classification considered as «primary» diabetes respectively.

[0029] Secondary diabetes comprises pancreatic, extrapancreatic/endocrine or drug-induced diabetes. Further, some types of diabetes are classified as exceptional forms. These include lipoatrophic, myatonic diabetes, and a type of diabetes caused by disturbance of insulin receptors.

[0030] Considering the high prevalence of diabetes in our society and the serious consequences associated therewith as discussed above, any therapeutic drug potentially useful for the treatment and prevention of this disease could have a profound beneficial effect on their health. There is a need in the art for a drug that will reduce the concentration of glucose in the blood of diabetic subjects without significant adverse side effects.

[0031] It is therefore an object of the present invention to provide a treatment regimen that is useful in lowering the blood glucose and to treat a diabetic condition.

[0032] It is yet another object of the invention to provide a treatment regimen that is useful in lowering the concentration of insulin in the blood, and to increase the ef-

fect of the remaining insulin.

STENOSIS

[0033] Many pathological conditions have been found to be associated with smooth muscle cell proliferation. Such conditions include restenosis, arteriosclerosis, coronary heart disease, thrombosis, myocardial infarction, stroke, smooth muscle neoplasms such as leiomyoma and leiomyosarcoma of the bowel and uterus and uterine fibroid or fibroma.

[0034] Over half a million interventional intravascular procedures are performed each year. While such invasive procedures continue to improve over time, as many as 30-50% of the procedures performed each year fail as a result of restenosis, i.e. the formation of secondary stenosis. The reduction of restenosis is, therefore, often cited as the most critical factor in increasing the success realised in the treatment of cardiovascular disease through the use of interventional intravascular procedures, such as angioplasty, atherectomy, and procedures utilising stents and laser technology.

[0035] In balloon angioplasty, e.g. Percutaneous Transluminal Coronary Angioplasty (PTCA), a small incision is made to an artery in the patient's leg or arm and a long hollow tube, called a guide catheter, is inserted into the artery. A thick guide wire and deflated balloon catheter are then inserted into the guide catheter and are carefully advanced through the patient's blood vessels using x-ray visualization. The deflated balloon is advanced until it reaches the site of the luminal narrowing, at which point the physician inflates the balloon one or more times to a pressure of about 4-6 atm for about 60 sec. When inflated, the balloon cracks and fractures the plaque and stretches the muscle fibre in the artery wall beyond its ability to recoil completely. Although no plaque is removed in this procedure, the fracturing of the plaque and the stretching of the arterial wall increase the vessel lumen, thereby allowing for increased blood flow.

[0036] The restenosis that accompanies such procedures is characterised by platelet aggregation and adhesion, smooth muscle cell proliferation, narrowing of the vessel lumen, restricted vasodilatation, and an increase in blood pressure. Smooth muscle cells in the intimal layer of the artery have been reported to enter the growth cycle within about 2-3 days of these procedures and to proliferate for several days thereafter (intimal hyperplasia).

[0037] Compounds that reportedly suppress smooth muscle proliferation in vitro may have undesirable pharmacological side effects when used in vivo. Heparin is an example of one such compound, which reportedly inhibits smooth muscle cell proliferation in vitro but when used in vivo has the potential adverse side effect of inhibiting coagulation.

[0038] As is apparent from the foregoing, many problems remain to be solved in the use of inhibitory drugs to effectively treat smooth muscle cell mobilisation and proliferation. It would be highly advantageous to develop new compositions or methods for inhibiting stenosis, restenosis or related disorders due to proliferation and mobilisation of vascular smooth muscle cells following, for example, traumatic injury to vessels rendered during vascular surgery.

[0039] It is anticipated that the compounds in accordance with the present invention will be effectively it the treatment of these diseases.

DETAILED DESCRIPTION OF THE INVENTION

[0040] The present invention relates to novel fatty acid analogues of the general formula (I):

$$R_1\text{-}[x_i\text{-}CH_2]_n\text{-}COOR_2 \quad (I)$$

- wherein R_1 is;
  - a C_6-C_{24} alkene with one or more double bonds and with one or more triple bonds, or
  - a C_6-C_{24} alkyne, and
- wherein R_2 represents hydrogen or C_1-C_4 alkyl, and
- wherein n is an integer from 1 to 12, and
- wherein i is an odd number and indicates the position relative to $COOR_2$, and
- wherein X_i independent of each other are selected from the group comprising O, S, SO, SO_2, Se and CH_2, and
- with the proviso that at least one of the X_i is not CH_2, and
- with the proviso that one of the carbon-carbon triple bonds is positioned between the (ω-1) carbon and the (ω-2) carbon, or between the (ω-2) carbon and the (ω-3) carbon, or between the (ω-3) carbon and the (ω-4) carbon,

or a salt, prodrug or complex thereof.

[0041] Most preferred embodiments of the present invention relates to compounds of formula (I) wherein a sulphur or selenium is arranged in position 3.

[0042] The present invention also relates to the use of a compound of the formula (II)

$$R_1\text{-}[X_1\text{-}CH_2]_n\text{-}COOR_2 \quad (II)$$

- wherein R_1 is;
  - a C_6-C_{24} alkene with one or more double bonds

and/or with one or more triple bonds, and/or
- a C_6-C_{24} alkyne, and/or
- a C_6-C_{24} alkyl substituted in one or several positions with one or more substituents selected from the group comprising fluoride, chloride, hydroxy, C_1-C_4 alkoxy, C_1-C_4 alkylthio, or C_2-C_5 acyloxy, and

- wherein R_2 represents hydrogen or C_1-C_4 alkyl, and

- wherein n is an integer from 1 to 12, and

- wherein i is an odd number and indicates the position relative to $COOR_2$, and

- wherein X_1 independent of each other are selected from the group comprising O, S, SO, SO_2, Se and CH_2, and

- with the proviso that at least one of the X_1 is not CH_2, and

- with the proviso that if R_1 is an alkyne, then one of the carbon-carbon triple bonds is positioned between the (ω-1) carbon and the (ω-2) carbon, or between the (ω-2) carbon and the (ω-3) carbon, or between the (ω-3) carbon and the (ω-4) carbon,

or a salt, prodrug or complex thereof, for the preparation of a pharmaceutical composition for the treatment and/or prevention of a condition selected from the group comprising syndrome X, obesity, hypertension, fatty liver, diabetes, hyperglycaemia, hyperinsulinemia, and stenosis, or for lowering the concentration of cholesterol and triglycerides in the blood of mammals, or for inhibiting the oxidative modification of low density lipoprotein, or for producing weight loss or a reduction of the fat mass in a human or non-human animal in need thereof.

[0043] The present invention also relates to a nutritional composition comprising a compound of formula (I), said composition being effective to reduce, or to prevent an increase in the total body weight or the total body fat mass in a human or non-human animal.

FIGURE LEGENDS

[0044] Figure 1 shows a scheme for the synthesis of the compound (Z) 3-Thia-heptadec-9-enoic-acid.

[0045] Figure 2 shows a scheme for the synthesis of 3-Thia-15-heptadecyne.

ADMINISTRATION OF THE COMPOUNDS OF THE PRESENT INVENTION

[0046] As a pharmaceutical medicament the compounds of the present invention may be administered directly to the animal by any suitable technique, including parenterally, intranasally, orally, or by absorption through the skin. They can be administered locally or systemically. The specific route of administration of each agent will depend, e.g., on the medical history of the animal.

[0047] The invention will be more fully understood by reference to the following examples. They should not, however, be construed as limiting the scope of the invention.

EXPERIMENTAL SECTION

METHODS

[0048] The methods described below were used as test systems for the compounds described in the prior art, and are thus also be used to test the biological effects of the present compounds.

Obese Zucker (fa/fa) rats.

[0049] The obese Zucker (fa/fa) rats used in this study were bred at the U 465 INSERM animal facility from pairs originally provided by the Harriet G. Bird Laboratory (Stow, MA, USA). Unless otherwise stated, the animals were maintained under a constant light-dark cycle (light from 7:00 a.m. to 7:00 p.m.) at 21±1 C° and were given free access to food and water. Three rats were housed per cage. Weight gains were recorded daily.

Wistar rats

[0050] Male Wistar Charles River rats weighing 280-358 were purchased from AnLab Ltd. (Prague, Czech Repubic) and housed in wire-mesh cages in a temperature (22±1 °C) and light-controlled (light from 7.00 a.m. to 7.00 p.m.) room. They were given free access to chow and water. Three rats were housed per cage. Weight gain and food intake were recorded daily.

Intravenous glucose tolerance tests

[0051] Male Zucker (fa/fa) rats (5 weeks old) were anaesthetised after a 5-hours fast, by intraperitoneal injection of sodium pentobarbital (50 mg/kg). The rats were injected with glucose (0.55 g/kg) in the saphenous vein and blood samples were collected from the tail vein in heparinized tubes at time 0, 5, 10, 15, 20 and 30 minutes after the glucose load. Samples were kept on ice, centrifuged and plasma was stored at -20 °C until analysis.

Hyperinsulinemic euglycemic clamp.

[0052] After 21 days on their respective diets (see above), the rats were anaesthetised by injection of xylazine hydrochloride (Rometar SPOFA, Prague, Czech Republic; 10 mg/ml) and ketamine hydrochloride (Narkamon SPOFA, Prague, Czech republic; 75 mg/ml), and fitted with chronic carotid artery and jugular vein cannulas as described by Koopmans et al. (Koopmans, S.J., et al.,

Biochim Biophys Acta, 1115, 2130-2138 1992.). The cannulated rats were allowed to recover for two days after surgery before the clamping studies which were carried out according to Kraegen et al. (Kraegen, E. W., et al., Am J Physiol, 248, E353-E362 1983.). Thus, on the third day after surgery, unrestrained conscious rats were given a continuous infusion of porcine insulin (Actrapid, Novo Nordisk, Denmark) at a dose of 6.4 mU per kg per min to achieve plasma insulin levels in the upper physiological range. The arterial blood glucose concentration was clamped at the basal fasting level, by variable infusion of a 30 % w/v glucose solution (Leciva, Prague, Czech Republic). Blood samples for determination of plasma glucose and insulin concentrations were obtained every 15 minutes from the start of the glucose infusion. After 90 minutes, the rats were disconnected from the infusions and immediately decapitated, blood was collected for plasma separation, liver and epididymal adipose tissue pads were dissected out and weighed.

Measurement of plasma parameters

[0053] Glucose (GLU, Boehringer Mannheim, Germany), free fatty acids (NEFA, C ACS-ACOD kit; Wako Chemicals, Dalton, USA) and b-hydroxybutyrate (310-A kit; Sigma Diagnostics Inc., St. Louis, USA) concentrations were measured using enzymatic methods. Insulin concentrations were determined with radioimmunoassay by (CIS bio International, Gif sur Yvette, France) using rat insulin as standard in the Zucker rats. In the Wistar Charles River rats, plasma glucose concentrations were measured with the aid of Beckman Glucose Analyzer (Fullerton, CA, USA). Plasma insulin levels were measured using a RIA kit from Linco Research Inc. (St. Charles, MO, USA). Phospholipids were measured by the enzymatic method of bioMérieux, Marcy-l'Etoile, France, Triacylglycerol by the Technicon Method no. SA9-0329L90, USA and Cholesterol by the Technicon Method no. SA4-0305L90, USA.

Preparation of post-nuclear and mitochondrial fractions and measurement of enzyme activities

[0054] Freshly isolated livers from individual old Zucker rats, were homogenised in ice-cold sucrose buffer (0.25 M sucrose, 10 mM HEPES (pH 7.4) and 2 mM EDTA). Post-nuclear and mitochondrial fractions were prepared using preparative differential centrifugation according to DeDuve *et al*. (De Duve, C., et al., Biochem. J., 60, 604-617 1955.) Modifications, purity and yield were as described earlier (Garras, A., et al., Biochim. Biophys. Acta, 1255, 154-160 1995.). Acid soluble products were measured in post-nuclear and mitochondrial enriched fractions, using [1-^{14}C]-palmitoyl-CoA and [1-^{14}C]-palmitoyl-L-carnitine (Radio-chemical Centre, Amersham, England) as substrates as described earlier (Willumsen, N., et al., J. Lipid Res., 34, 13-22 1993. Carnitine palmitoyltransferase-I and -II activities were measured in the post-nuclear and mitochondrial fractions essentially as described by Bremer (Bremer, J., Biochim. Biophys. Acta, 665, 628-631 1981.) and 3-hydroxy-3-methylglutharyl-CoA synthase was measured according to Clinkenbeard et al. (Clinkenbeard, K. D., et al., J. Biol. Chem, 250, 3108-3116 1975.) in the mitochondrial fractions.

RNA analysis

[0055] RNA extraction (Chomczynski, P., et al., Anal. Biochem., 162, 156-159 1987.), Northern blot analysis and slot blotting of RNA onto nylon filters, and hybridisation to immobilised RNA were performed as earlier described (Vaagenes, H., et al., Biochem. Pharmacol., 56, 1571-1582 1998.). The following cDNA fragments were used as probes: CPT-I, (Esser, V. et al., J. Biol. Chem., 268,5817-5822 1993), CPT-II (Woeltje, K. F., et al., J. Biol. Chem., 265, 10720-10725 1990.), 3-hydroxy-3-methylglutharyl-CoA synthase (Ayté, J., et al., Proc. Natl. Acad. Sci. USA., 87, 3874-3878 1990.), and hormone sensitive lipase (Holm, C., et al., Biochim. Biophys. Acta, 1006, 193-197 1989.). The relative levels of RNA expression were estimated as the amounts of radioactive probe hybridised to the respective levels of 28S rRNA.

RESULTS

[0056] In the examples below, Example 1A) represents a reference example not forming part of the invention

Example 1. Synthesis of novel fatty acid compounds

A) Non-β-oxidizable fatty acid analogous with a carbon-carbon double bond.

[0057] The synthesis of a compound in accordance with the present invention is representatively elaborated with reference to the synthesis of the thia-heptadec-9-enoic acid;

(Z) $HO(O)C\text{-}CH_2\text{-}S\text{-}(CH_2)_5\text{-}CH{=}CH\text{-}C_7H_{15}$

(Z) designates a cis configuration.

1. Preparation of 1-bromo-5-hydroxy-pentane

[0058] Pentane-1,5-diol, HO-(CH2)5-OH, was treated with HBr in benzene and refluxed for 24 h. The product mixture was chromatographed first with a 85:15 hexane-diethyl ether mixture to remove the dibromide and then with a 70:30 mixture. Yield of 1-bromo-5-hydroxy-pentane, 80 %.

[0059] ^{1}H-NMR: 1,81(-CH_2-CH_2OH), 1,44(-CH_2-), 3,35(-CH_2-Br), 3,55(-CH_2-OH), 3,32(-OH), 1,51(-CH_2-CH_2Br).

[0060] ^{13}C-NMR: 31,43-32,30(C_2,C_4), 24,24(C_3), 33,64(C_5), 62,11(C_1).

2. Preparation of 5-(tetrahydropyranyloxy)-1-bromopentane

[0061] This compound was allowed to react with 3,4-dihydro-2H-pyrane in CH_2Cl_2 at 0 °C. 2 drops of conc. HCl was used as catalyst. After removal of the solvent the reaction product was chromatographed in 95:5 hexane-diethyl ether. The yield of 5-(tetrahydropyranyloxy)-1-bromopentane was 77 %.

[0062] ^{1}H-NMR: 1,45-1,63(-CH_2-), 1,83(-CH_2-CH_2-O-), 3,38(-CH_2-Br), 3,27-3,79(-CH_2-O-), 4,52(-O-CH-O).

[0063] ^{13}C-NMR: 24,9-32,92(C_2-C_4), 33,61C_5), 62,26 (C_6), 98,83 (C_1 in THP).

3. Preparation of 7-(tetrahydropyranyloxy)-1-heptyne

[0064] The product from step 2 was treated with the EDA complex of Li-acetylide in dry dimethyl sulfoxide at 0 °C under argon. After 4 h at room temperature the reaction mixture was hydrolysed with water and organic products extracted with diethyl ether. The residue after removing the ether was chromatographed in 97:3 hexane-diethyl ether, yielding 7-(tetrahydropyranyloxy)-1-heptyne in 62 % yield.

[0065] ^{1}H-NMR: 1,45-1,66(-CH_2-), 3,45-3,82(-CH_2-O), 2,16(-CH_2-C≡), 1,90(HC≡C-), 4,53(-O-CH-O-).

[0066] ^{13}C-NMR: 18,27-30,66(C_3-C_6), 62,21(C_7), 68,14 (C_1), 84,40(C_2).

4. Preparation of 1-(tetrahydropyranyloxy)-tetradec-6-yne

[0067] To a 1,6 M solution of BuLi in hexane dissolved in THF at 0 °C under argon and the product from 3 was added a mixture of 1-bromoheptane and N,N-dimethylpropyleneurea. After hydrolysis, extraction and chromatography 1-(tetrahydropyranyloxy)-tetradec-6-yne was isolated in 69 % yield.

[0068] ^{1}H-NMR: 0,85(CH_3-), 1,22-1,57(-CH_2-), 2,10(-CH_2-C≡), 3,30-3,84(-CH_2O-), 4,55(-O-CH-O-).

[0069] ^{13}C-NMR: 14,02(C_{14}), 22,60-31,73(C_2-C_{13}), 18,69-18,71(C_5 og C_8), 62,23(C_1), 79,91-80,32(C_6 og C_7).

5. Preparation of 1(Tetrahydropyranyloxy)-tetradec-6-ene

[0070] The substituted tetradec-6-yne from step 4 was reduced with hydrogen in the presence of the Lindlar catalyst in ethanol. The reduction lasted for 4 h. 1(Tetrahydropyranyloxy)-tetradec-6-ene appeared sufficiently pure for step 6 without further purification but could be isolated in 89 % yield after chromatography.

[0071] ^{1}H-NMR: 0,90(CH_3-), 1,27-1,61(-CH_2-), 3,39-3,89(-CH_2-O), 2,04(-CH_2-C=), 4,59(-O-CH-O-), 5,37 (-HC=CH-).

[0072] ^{13}C-NMR: 14,07(C_{14}), 22,65-31.85(C_2-C_{13}), 62,27(C_1), 27,13, 27,19(C_5 and C_8), 129,60-130,04(C_6 and C_7).

6. Preparation of 1-bromotetradec-6-ene

[0073] The product from 5 was brominated with CBr_4 at 0 °C in dichloromethane in the presence of Ph_3P. The reaction mixture was stirred overnight. The yield of 1-bromotetradec-6-ene was quantitative.

[0074] ^{1}H-NMR: 0,87(CH_3-), 1,27-1,52(-CH_2-), 2,01(-CH_2-C=), 3,39(-CH_2-Br), 1,45(-CH_2-CH_2-Hr), 1,85(-CH_2-CH_2C=), 5,34(-HC=CH-).

[0075] ^{13}C-NMR: 14,00(C_{14}), 22,60-32,68(C_2-C_{13}), 26,97, 27,24(C_5 and C_8), 33,75(C_1), 129,15-130,32(C_6 and C_7).

7. Preparation of (Z) thia-heptadec-9-enoic acid.

[0076] The bromodecene from step 6 in methanol was added to 3 equivalents of KOH and 1.5 equivalents of HS-CH_2-C(O)OH in methanol under argon during 30 min. After stirring at room temperature for 4 h, refluxing for another 12 h, followed by hydrolysis and extraction with diethyl ether, then acidifying to pH 1-2, the product, the title compound, was isolated as viscous oil in 60 % yield.

[0077] The following analyses have been performed; IR, 600 MHz 1H and 13C NMR, MS, GC, GC-MS of the methyl ester. The NMR results are given below. All data are given in parts per million (ppm). No trace of the E-compound could be detected.

[0078] 1H-NMR : 0.86 (CH3-), 1.16-1.60 (-CH2-), 1.99 (-CH2-C=), 2.64 (-CH2-S-), 3.22 (-S-CH2-C(O)OH), 5.33 (HC=CH).

[0079] 13C-NMR : 176.63 (C1), 33.34 (C2), 32.69 (C4), 22.63-31.83 (C5-C7,C12-C16), 129.32 and 130.24 (C9, C10), 26.98 and 27.19 (C8, C11), 14.08(C17).

B) Non-β-oxidizable fatty acid analogous comprising a carbon-carbon triple binding.

[0080] The synthesis of a compound in accordance with the present invention is representatively elaborated with reference to the synthesis of the 3-Thia-15-heptadecyne, as given in figure 1.

1. Preparation of 11-Bromo-1(tetrahydro-2-pyranyloxy) undecane.

[0081] Pyridine toluene 4-sulphonate (1,0 g, 4,0 mmol) and 11-Bromo-1-undecanol (10,0 g, 400 mmol) were dissolved in dry CH2CH2 (200 ml) at ambient temperature, and 3,4-dihydro-2H-pyrane (5,0 g, 60 mmol) was added. The reaction mixture was stirred overnight. The crude product was purified by flash chromatography on silica gel eluted with CH_2Cl_2. The yield of 11-Bromo-1(tetrahydro-2-pyranyloxy)undecane was 10,7 g (80%).

2. Preparation of 14-(tetrahydro-2-pyranoyl)-2-tetradecyne.

[0082] Propyne gas was bubbled through a solution of MeLi in diethyl ether (0,8 M, 60 ml, 51,2 mmol) in a rate adapted to ensure reflux of the ether. When there were no longer any heat development, the reaction was considered finished (white slurry). 11-Bromo-1(tetrahydro-2-pyranyloxy) undecane (product 2) (13,0 g, 38,8 mmol) was added drop by drop to this solution over a period of 20 minutes. The reaction was stirred overnight, and water (50 ml) was carefully added drop by drop. The mixture was diluted with diethyl ether and washed with water (5x), dried ($MgSO_4$) and the solvent was evaporated off. The crude product was purified by flash chromatography with CH_2Cl_2 as eluent. The yield of 14-(tetrahydro-2-pyranoyl)-2-tetradecyne was 8,5 g (74%).

3. Preparation of 12-Tetradecyn-1-ol

[0083] Pyridine Toluene 4-Sulphonate (0,3 g, 1,2 mmol) and the alkyne (product 3) were dissolved in ethanol (25 ml) and heated to 50 °C overnight. The solvent was evaporated and distributed between water and CH_2CL_2. The water phase was washed with water, dried ($MgSO_4$) and the solvent was evaporated. The crude product was purified with flash chromatography with CH_2Cl_2 as eluent. The yield of 12-Tetradecyn-1-ol was 1,5 g (78%).

4. Preparation of 19-Bromo-2-tetradecyne

[0084] 12-Tetradecyn-1-ol (5,0, 23,8 mmol) was dissolved in hexane (50ml) and 10 drops of pyridine was added. PBr_3 was added to this mixture. The mixture was heated to 60 °C for three hours, cooled, and water was added drop by drop. The mixture was washed by water, dried ($MgSO_4$) and the solvent was evaporated. The crude product was purified with flash chromatography with hexane as eluent until 2,5 % EtOAc in hexane. The yield of 14-Bromo-2-tetradecyne was 2,2 g (34%).

5. Preparation of 3-Thia-15-heptadecyne

[0085] KOH (2,76 g, 49,0 mmol) was dissolved in methanol (30 ml), and thioglycolic acid (2,04 g, 22,1 mmol) in methanol (25 ml) was added drop by drop. After 10 minutes the 14-Bromo-2-tetradecyne (5,5 g, 20,1 mmol) was carefully added drop by drop, and the mixture was heated to 50 °C overnight. The mixture was cooled to 0°C, and 30 ml HCl was added (pH = 1). The precipitate was filtered and washed with water (2x). The solid material was dissolved in chloroform (100 ml) and washed with water (1x), dried ($MgSO_4$) and the solvent was evaporated off. The yield of the compound 14-Bromo-2-tetradecyne was 4,4 g (77 %).

[0086] ^1H NMR (300 MHz, $CDCl_3$) δ: 1.25 (10 H, sharp m), 1.3-1.4 (4 H, m), 1.46 (2 H, quint, *J* = 7.0 Hz, ≡CCH$_2$C*H*$_2$-), 1.60 (2 H, quint, *J* = 7.0 Hz, -C*H*$_2$CH$_2$S-), 1.77 (3 H, t, *J* = 2.6 Hz, C*H*$_3$C≡), 2.10 (2 H, tq, *J* = 2.6. 7.0 Hz, ≡CC*H*$_2$-), 2.65 (2 H, t, *J* = 7.3 Hz, -C*H*$_2$S-), 3.25 (2 H, s, -SC*H*$_2$COOH), 10.40 (1 H, broad s, -COO*H*).

[0087] ^{13}C NMR (75 MHz, $CDCl_3$) δ: 3.35 (CH$_2$C≡), 18.61 (≡C*C*H$_2$-), 28.50, 28.78, 28.78, 28.97, 29.04, 29.04, 29.34, 29.38, 29.40, 32.70 (-CH$_2$*C*H$_2$S-), 33.3 (-S*C*H$_2$CO), 75.20 (MeC≡C-), 79.31 (MeC≡C-), 176.42 (CO).

C) Non-β-oxidizable fatty acid analogous substituted in one or several positions.

[0088] One or several of the hydrogen groups of the fatty acid chain can be substituted with one or more of the compounds selected from the group comprising fluoride, chloride, hydroxy, C_1-C_4 alkoxy, C_1-C_4 alkylthio, C_2-C_5 acyloxy or C_1-C_4 alkyl. The substituents can for instance be incorporated in the formula (I) compound by selecting other substrates in the steps 1-4 above.

[0089] Finally, the compounds prepared in step (C) above can be converted to saturated compounds with a traditionally hydrogenation reaction, thus giving an R1 group which is fully saturated (i.e. an alkyl), but substituted at one or more positions.

Example 2

Toxicity study of TTA

[0090] Toxicity studies, and test for mutagenic activity will be performed as described in PCT/N099/00135.

Example 3.

[0091] The biological activity of the novel compounds in accordance with the present invention will be determined as described in the experimental section above, or as disclosed in the publications cited above.

Claims

1. Fatty acid analogues of the general formula (I):

$$R_1\text{-}[x_i\text{-}CH_2]_n\text{-}COOR_2 \qquad (I)$$

- wherein R_1 is;

  - a C_6-C_{24} alkene with one or more double bonds and with one or more triple bonds, or

- a C_6-C_{24} alkyne, and
- wherein R_2 represents hydrogen or C_1-C_4 alkyl, and
- wherein n is an integer from 1 to 12, and
- wherein i is an odd number and indicates the position relative to $COOR_2$, and

- wherein X_1 independent of each other are selected from the group comprising O, S, SO, SO_2, Se and CH_2, and
- with the proviso that at least one of the X, is not CH_2, and
- with the proviso that one of the carbon-carbon triple bonds is positioned between the (ω-1) carbon and the (ω-2) carbon, or between the (ω-2) carbon and the (ω-3) carbon, or between the (ω-3) carbon and the (ω-4) carbon,

or a salt, prodrug or complex thereof.

2. Fatty acid analogues in accordance with claim 1, wherein the R_1 moiety comprises one carbon-carbon triple bond.

3. Fatty acid analogues in accordance with claim 1 or 2, wherein the $X_{1=3}$ is sulphur.

4. Fatty acid analogues in accordance with claim 1 or 2, wherein $X_{1=3}$ is selenium.

5. Use of a compound of the formula (II)

$$R_1\text{-}[x_i\text{-}CH_2]_n\text{-}COOR_2 \qquad (II)$$

- wherein R_1 is;

  - a C_6-C_{24} alkene with one or more double bonds and/or with one or more triple bonds, and/or
  - a C_6-C_{24} alkyne, and/or
  - a C_6-C_{24} alkyl substituted in one or several positions with one or more substituents selected from the group comprising fluoride, chloride, hydroxy, C_1-C_4 alkoxy, C_1-C_4 alkylthio, or C_2-C_5 acyloxy, and

- wherein R_2 represents hydrogen or C_1-C_4 alkyl, and
- wherein n is an integer from 1 to 12, and
- wherein i is an odd number and indicates the position relative to $COOR_2$, and
- wherein X, independent of each other are selected from the group comprising O, S, SO, SO_2, Se and CH_2, and
- with the proviso that at least one of the X, is not CH_2, and
- with the proviso that if R_1 is an alkyne, then one of the carbon-carbon triple bonds is positioned between the (ω-1) carbon and the (ω-2) carbon, or between the (ω-2) carbon and the (ω-3) carbon, or between the (ω-3) carbon and the (ω-4) carbon,

or a salt, prodrug or complex thereof, for the preparation of a pharmaceutical composition for the treatment and/or prevention of a condition selected from the group comprising syndrome X, obesity, hypertension, fatty liver, diabetes, hyperglycaemia, hyperinsulinemia, and stenosis, or for lowering the concentration of cholesterol and triglycerides in the blood of mammals, or for inhibiting the oxidative modification of low density lipoprotein, or for producing weight loss or a reduction of the fat mass in a human or non-human animal in need thereof.

6. A nutritional composition comprising fatty acid analogues of the general formula (I) in claim 1.

Patentansprüche

1. Fettsäureanaloga der allgemeinen Formel (I):

$$R_1\text{-}[X_i\text{-}CH_2]_n\text{-}COOR_2 \qquad (I)$$

- wobei R_1

  - ein C_6-C_{24}-Alken mit einer oder mehreren Doppelbindung(en) und mit einer oder mehreren Dreifachbindung(en), oder
  - ein C_6-C_{24}-Alkin

ist, und
- wobei R_2 Wasserstoff oder C_1-C_4-Alkyl darstellt, und
- wobei n eine ganze Zahl von 1 bis 12 ist, und
- wobei i eine ungerade Zahl ist und die Position relativ zu $COOR_2$ anzeigt, und
- wobei X_i unabhängig voneinander ausgewählt sind aus der Gruppe umfassend O, S, SO, SO_2, Se und CH_2, und
- unter der Maßgabe, dass wenigstens einer der X_i nicht CH_2 ist, und
- unter der Maßgabe, dass eine der Kohlenstoff-Kohlenstoff-Dreifachbindungen zwischen dem (ω-1)-Kohlenstoff und dem (o-2)-Kohlenstoff, oder zwischen dem (ω-2)-Kohlenstoff und dem (ω-3)-Kohlenstoff, oder zwischen dem (ω-3)-Kohlenstoff und dem (ω-4)-Kohlenstoff positioniert ist,

oder ein Salz, ein Prodrug oder Komplex davon.

2. Fettsäureanaloga nach Anspruch 1, wobei die R_1-Gruppierung eine Kohlenstoff-Kohlenstoff-Dreifachbindung umfasst.

3. Fettsäureanaloga nach Anspruch 1 oder 2, wobei das $X_{i=3}$ Schwefel ist.

4. Fettsäureanaloga nach Anspruch 1 oder 2, wobei $X_{i=3}$ Selen ist.

5. Verwendung einer Verbindung der Formel (II)

$$R_1\text{-}[X_i\text{-}CH_2]_n\text{-}COOR_2 \qquad (II)$$

- wobei R_1

  - ein C_6-C_{24}-Alken mit einer oder mehreren Doppelbindung(en) und/oder mit einer oder mehreren Dreifachbindung(en), und/oder
  - ein C_6-C_{24}-Alkin und/oder
  - ein C_6-C_{24}-Alkyl, substituiert in einer oder mehreren Positionen mit einem oder mehreren Substituenten, ausgewählt aus der Gruppe, umfassend Fluorid, Chlorid, Hydroxy, C_1-C_4-Alkoxy, C_1-C_4-Alkylthio oder C_2-C_5-Acyloxy,

  ist, und
- wobei R_2 Wasserstoff oder C_1-C_4-Alkyl darstellt, und
- wobei n eine ganze Zahl von 1 bis 12 ist, und
- wobei i eine ungerade Zahl ist und die Position relativ zu $COOR_2$ anzeigt, und
- wobei X_i unabhängig voneinander ausgewählt sind aus der Gruppe, umfassend O, S, SO, SO_2, Se und CH_2, und
- unter der Maßgabe, dass wenigstens eines der X_i nicht CH_2 ist, und
- unter der Maßgabe, dass, falls R_1 ein Alkin ist, dann eine der Kohlenstoff-Kohlenstoff-Dreifachbingungen zwischen dem (ω-1)-Kohlenstoff und dem (ω-2)-Kohlenstoff, oder zwischen dem (ω-2)-Kohlenstoff und dem (ω-3)-Kohlenstoff, oder zwischen dem (ω-3)-Kohlenstoff und dem (ω-4)-Kohlenstoff positioniert ist,

oder eines Salzes, Prodrugs oder Komplexes davon, zur Herstellung einer pharmazeutischen Zusammensetzung zur Behandlung und/oder Prävention eines Zustands, ausgewählt aus der Gruppe umfassend Syndrom X, Fettsucht, Bluthochdruck, Fettleber, Diabetes, Hyperglykämie, Hyperinsulinämie und Stenose, oder zum Erniedrigen der Konzentration von Cholesterin und Triglyceriden im Blut von Säugern, oder zum Inhibieren der oxidativen Modifikation von Lipoprotein mit geringer Dichte, oder zum Erzeugen von Gewichtsverlust oder einer Reduktion der Fettmasse in einem Menschen oder nicht-menschlichen Tier, der/das Bedarf dafür hat.

6. Nährstoffzusammensetzung, umfassend Fettsäureanaloga der allgemeinen Formel (I) in Anspruch 1.

Revendications

1. Analogues d'acides gras de formule générale (I) :

$$R_1\text{-}(X_i\text{-}CH_2)_n\text{-}COOR_2 \qquad (I)$$

- où R_1 est :

  - un alcène en C_6-C_{24} avec une ou plusieurs doubles liaisons et une ou plusieurs triples liaisons, ou
  - un alcyne en C_6-C_{24}, et

- où R_2 représente un atome d'hydrogène ou un groupe alkyle en C_1-C_4 et
- où n est un entier de 1 à 12 et
- où i est un nombre impair et indique la position par rapport à $COOR_2$, et
- où les X_i, indépendamment les uns des autres, sont choisis dans le groupe comprenant O, S, SO, SO_2, Se et CH_2 et
- sous réserve qu'au moins un des X_i ne soit pas CH_2 et
- sous réserve qu'une des triples liaisons carbone-carbone soit positionnée entre l'atome de carbone (ω - 1) et l'atome de carbone (ω - 2) ou entre l'atome de carbone (ω - 2) et l'atome de carbone (ω - 3) ou entre l'atome de carbone (ω - 3) et l'atome de carbone (ω - 4),

ou un sel, un précurseur de médicament ou un complexe de ceux-ci.

2. Analogues d'acides gras selon la revendication 1, où le groupe R_1 comprend une triple liaison carbone-carbone.

3. Analogues d'acides gras selon la revendication 1 ou 2, où $X_{i=3}$ est du soufre.

4. Analogues d'acides gras selon la revendication 1 ou 2, où $X_{i=3}$ est du sélénium.

5. Utilisation d'un composé de formule (II)

$$R_1\text{-}(X_i\text{-}CH_2)_n\text{-}COOR_2 \qquad (II)$$

- où R_1 est :

  - un alcène en C_6-C_{24} avec une ou plusieurs doubles liaisons et/ou une ou plusieurs triples liaisons, et/ou
  - un alcyne en C_6-C_{24}, et/ou
  - un alkyle en C_6-C_{24} substitué en une ou plusieurs positions par un ou plusieurs substituants choisis dans le groupe comprenant le fluorure, le chlorure, les groupes hydroxy, alcoxy en C_1-C_4, alkylthio en C_1-C_4 ou acyloxy en C_2-C_5, et

- où R_2 représente un atome d'hydrogène ou un groupe alkyle en C_1-C_4 et

- où n est un entier de 1 à 12 et
- où i est un nombre impair et indique la position par rapport à $COOR_2$, et
- où les X_i, indépendamment les uns des autres, sont choisis dans le groupe comprenant O, S, SO, SO_2, Se et CH_2 et
- sous réserve qu'au moins un des X_i ne soit pas CH_2 et
- sous réserve que, si R_1 est un alcyne, alors une des triples liaisons carbone-carbone soit positionnée entre l'atome de carbone (ω - 1) et l'atome de carbone (ω - 2) ou entre l'atome de carbone (ω - 2) et l'atome de carbone (ω - 3) ou entre l'atome de carbone (ω - 3) et l'atome de carbone (ω - 4),

ou un sel, un précurseur de médicament ou un complexe de ceux-ci, pour la préparation d'une composition pharmaceutique pour le traitement et/ou la prévention d'une pathologie choisie dans le groupe comprenant le syndrome X, l'obésité, l'hypertension, la stéatose hépatique, le diabète, l'hyperglycémie, l'hyperinsulinémie et la sténose, ou pour diminuer la concentration du cholestérol et des triglycérides dans le sang des mammifères, ou pour inhiber la modification des lipoprotéines de basse densité par oxydation, ou pour produire une perte de poids ou une réduction de la masse grasse chez un homme ou un animal non-humain le nécessitant.

6. Composition nutritionnelle comprenant des analogues d'acides gras de formule générale (I) selon la revendication 1.

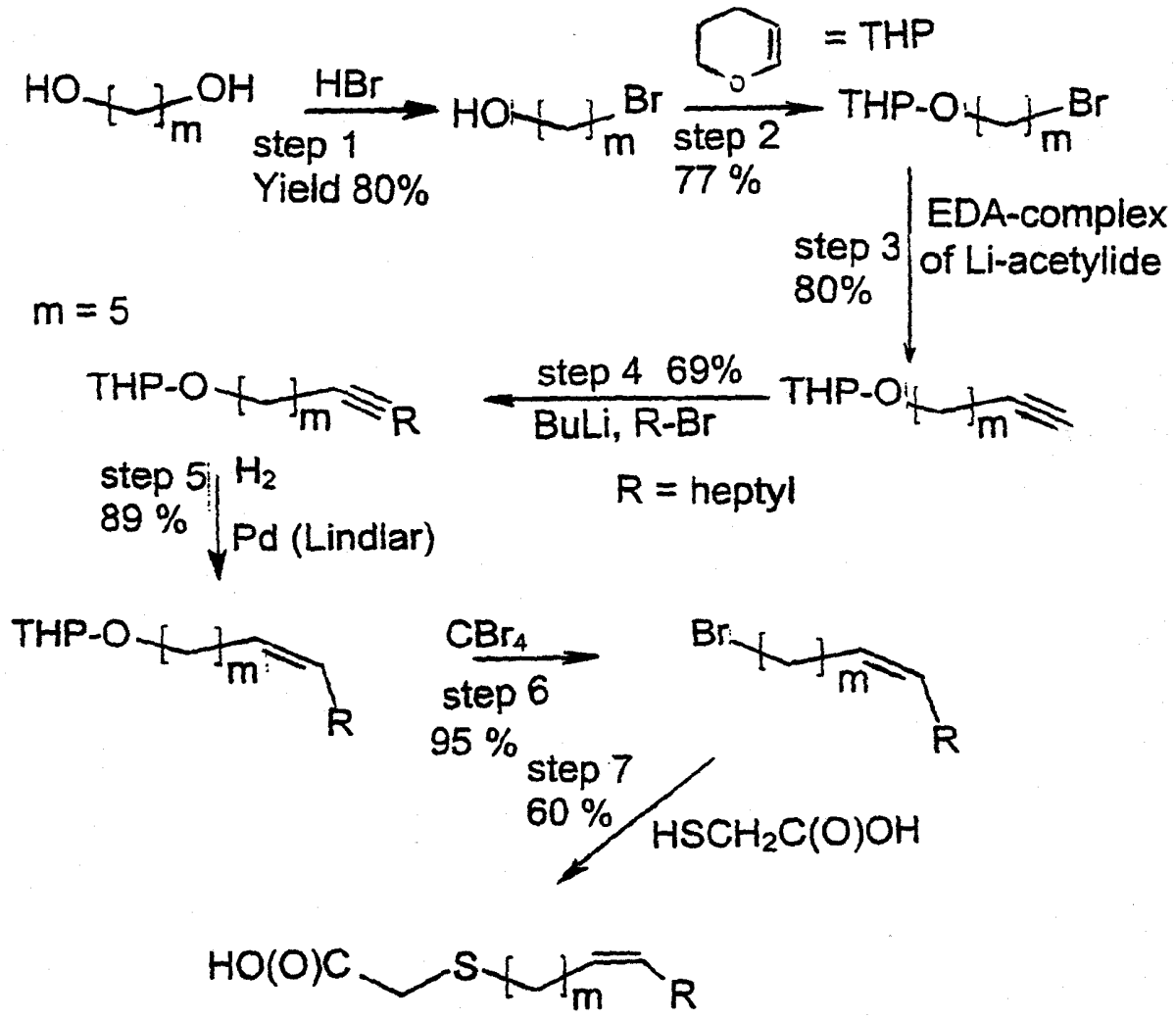
HO OH
m
HBr
step 1
Yield 80%
HO Br
m
= THP
step 2
77 %
THP-O Br
m
step 3
80%
EDA-complex
of Li-acetylide
m = 5
THP-O
m
R
step 4 69%
BuLi, R-Br
THP-O
m
R = heptyl
step 5
89 %
H2
Pd (Lindlar)
THP-O
m
R
CBr4
step 6
95 %
Br
m
R
step 7
60 %
HSCH2C(O)OH
HO(O)C
S
m
R

Figure 1

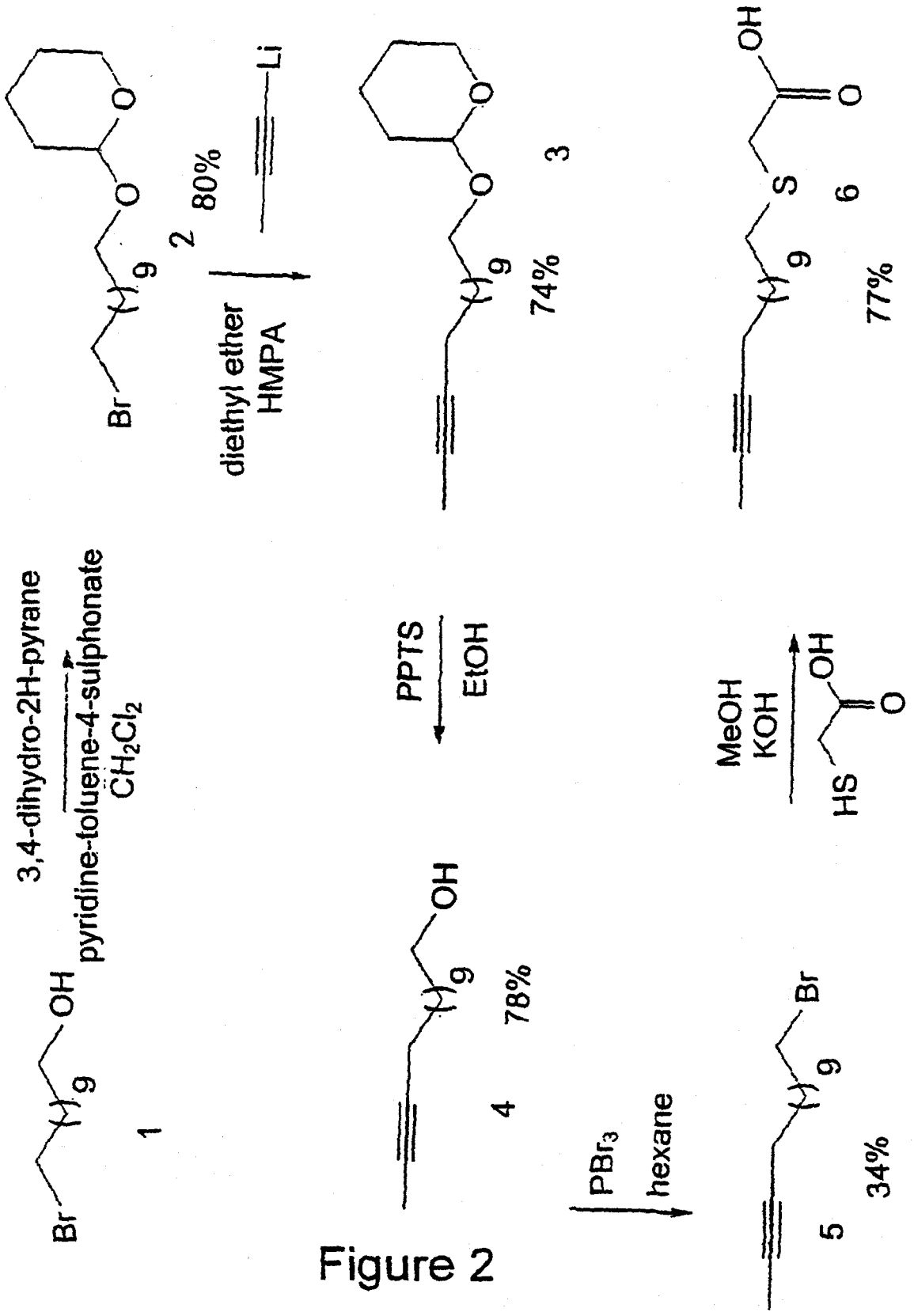
3,4-dihydro-2H-pyrane
pyridine-toluene-4-sulphonate
CH_2Cl_2
1
2
80%
diethyl ether
HMPA
3
74%
PPTS
EtOH
4
78%
PBr_3
hexane
5
34%
MeOH
KOH
6
77%

Figure 2