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(54) **Title:** NEW EXENDIN-4 DERIVATIVES AS SELECTIVE PEPTIDIC DUAL GLP-1 / GLUCAGON RECEPTOR AGONISTS

(57) **Abstract:** The present invention relates to dual GLP-1 / glucagon receptor agonists and their medical use, for example in the treatment of disorders of the metabolic syndrome, including diabetes and obesity, as well as for reduction of excess food intake.



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## New Exendin-4 Derivatives as selective peptidic dual GLP-1 / Glucagon Receptor Agonists

5

### Description

### FIELD OF THE INVENTION

- 10 The present invention relates to dual GLP-1 / glucagon receptor agonists and their medical use, for example in the treatment of disorders of the metabolic syndrome, including diabetes and obesity, as well as for reduction of excess food intake. These dual GLP-1 / glucagon receptor agonists show reduced activity on the GIP receptor to reduce the risk of hypoglycemia. They are structurally derived from exendin-4 and
- 15 show high solubility and stability under acidic conditions in the presence of antimicrobial preservatives like m-cresol or phenol which makes them especially suited for combinations with other antidiabetic compounds.

### BACKGROUND OF THE INVENTION

20

- Pocai et al (Diabetes 2009, 58, 2258-2266), Day et al. (Nat Chem Biol 2009,5,749-757) and Kosinski et al. (Obesity 2012, 20, 1566-1571) describe dual agonists of the glucagon-like peptide-1 (GLP-1) and glucagon receptors, e.g. by combining the actions of GLP-1 and glucagon in one molecule, which lead to a therapeutic principle
- 25 with anti-diabetic action and a pronounced weight lowering effect superior to pure GLP-1 agonists, among others due to glucagon-receptor mediated increased satiety and energy expenditure.

- Holst (Physiol. Rev. 2007, 87, 1409-1439) and Meier (Nat. Rev. Endocrinol. 2012, 8, 728-742) describe that GLP-1 receptor agonists, such as GLP-1, liraglutide and exendin-4, have 3 major pharmacological activities to improve glycemic control in patients with T2DM (type 2 diabetes mellitus) by reducing fasting and postprandial glucose (FPG and PPG): (i) increased glucose-dependent insulin secretion (improved first- and second-phase), (ii) glucagon suppressing activity under
- 30

hyperglycemic conditions, and (iii) delay of gastric emptying rate resulting in retarded absorption of meal-derived glucose.

The amino acid sequence of GLP-1(7-36)-amide is shown as SEQ ID NO: 1.

5

HAEGTFTSDVSSYLEGQAAKEFIAWLVKGR-NH<sub>2</sub>

Liraglutide is a marketed chemically modified GLP-1 analog in which, among other modifications, a fatty acid is linked to a lysine in position 20 leading to a prolonged duration of action (Drucker et al, Nat. Rev. Drug Disc. 2010, 9, 267-268, ; Buse et al., Lancet 2009, 374, 39-47).

10

The amino acid sequence of Liraglutide is shown as SEQ ID NO: 2.

15

HAEGTFTSDVSSYLEGQAAK((S)-4-Carboxy-4-hexadecanoylamino-butyl-)  
EFIAWLVRGRG-OH

Glucagon is a 29-amino acid peptide which is released into the bloodstream when circulating glucose is low. Glucagon's amino acid sequence is shown as SEQ ID NO:

20

3.

HSQGTFTSDYSKYLDNRRAQDFVQWLMNT-OH

During hypoglycemia, when blood glucose levels drop below normal, glucagon signals the liver to break down glycogen and release glucose, causing an increase of blood glucose levels to reach a normal level. Recent publications suggest that glucagon has in addition beneficial effects on reduction of body fat mass, reduction of food intake, and increase of energy expenditure (see e.g. Heppner et al., Physiology & Behavior 2010, 100, 545–548).

25

30

GIP (glucose-dependent insulintropic polypeptide) is a 42 amino acid peptide that is released from intestinal K-cells following food intake. GIP and GLP-1 are the two gut enteroendocrine cell-derived hormones accounting for the incretin effect, which accounts for over 70% of the insulin response to an oral glucose challenge (Baggio

et al. Gastroenterology 2007, 132, 2131–2157).

GIP's amino acid sequence is shown as SEQ ID NO: 5.

5   YAEGTFISDYSIAMDKIHQQDFVNWLLAQKGKKNDWKHNITQ-OH

Peptides which are based on the structures of GLP-1 or glucagon, and bind and activate both the glucagon and the GLP-1 receptor (Hjorth et al. Journal of Biological Chemistry, 1994, 269, 30121-30124; Day et al, Nature Chem Biol, 2009, 5, 749-757) and suppress body weight gain and reduce food intake are described in patent applications WO 2008/071972, WO 2008/101017, WO 2009/155258, WO 2010/096052, WO 2010/096142, WO 2011/075393, WO 2008/152403, WO 2010/070251, WO 2010/070252, WO 2010/070253, WO 2010/070255, WO 2011/160630, WO 2011/006497, WO 2011/087671, WO 2011/087672, WO 2011/117415, WO 2011/117416, WO 2012/150503, WO 2012/158965, WO 2012/177444, WO 2013/004983, WO 2013/092703, WO 2014/017843, WO 2014/041195, WO 2014/041375, WO 2014/081872, WO 2014/140222, WO 2014/170496, WO 2015/055801, WO 2015/055802, WO 2015/132599, WO 2016/045400, WO 2016/055610 and WO 2016/065090, the contents of which are herein incorporated by reference. Other peptidic dual agonists are described in WO 2012/177443, WO 2013/186240, WO 2014/056872, WO 2014/091316, WO 2015/086731, WO 2015/086732 and WO 2015/086733, the contents of which are herein incorporated by reference. The body weight reduction was shown to be superior to pure GLP-1 agonists.

25   Exendin-4 is a 39 amino acid peptide which is produced by the salivary glands of the Gila monster (*Heloderma suspectum*) (Eng et al., J. Biol. Chem. 1992, 267, 7402-7405). Exendin-4 is an activator of the GLP-1 receptor, whereas it shows low activation of the GIP receptor and does not activate the glucagon receptor (see Table 1).

30   Table 1: Potencies of exendin-4 at human GLP-1, GIP and Glucagon receptors (indicated in pM) at increasing concentrations and measuring the formed cAMP as described in Methods.

SEQ ID NO:	peptide	EC50 hGLP-1 R [pM]	EC50 hGIP R [pM]	EC50 hGlucagon R [pM]
4	exendin-4	0.4	12500.0	>10000000

The amino acid sequence of exendin-4 is shown as SEQ ID NO: 4.

## 5 HEGTFTSDLSKQMEEEAVRLFIEWLKNGGPSSGAPPPS-NH<sub>2</sub>

Exendin-4 shares many of the glucoregulatory actions observed with GLP-1. Clinical and nonclinical studies have shown that exendin-4 has several beneficial antidiabetic properties including a glucose dependent enhancement in insulin synthesis and secretion, glucose dependent suppression of glucagon secretion, slowing down gastric emptying, reduction of food intake and body weight, and an increase in beta-cell mass and markers of beta cell function (Gentilella et al., Diabetes Obes Metab., 2009, 11, 544-556; Norris et al, Diabet Med., 2009, 26, 837-846; Bunck et al, Diabetes Care., 2011, 34, 2041-2047).

These effects are beneficial not only for diabetics but also for patients suffering from obesity. Patients with obesity have a higher risk of getting diabetes, hypertension, hyperlipidemia, cardiovascular and musculoskeletal diseases.

Relative to GLP-1, exendin-4 is resistant to cleavage by dipeptidyl peptidase-4 (DPP4) resulting in a longer half-life and duration of action in vivo (Eng J., Diabetes, 1996, 45 (Suppl 2):152A (abstract 554)).

Exendin-4 was also shown to be much more stable towards degradation by neutral endopeptidase (NEP), when compared to GLP-1, glucagon or oxyntomodulin (Druce et al., Endocrinology, 2009, 150(4), 1712-1722). Nevertheless, exendin-4 is chemically labile due to methionine oxidation in position 14 (Hargrove et al., Regul. Pept., 2007, 141, 113-119) as well as deamidation and isomerization of asparagine in position 28 (WO 2004/035623).

Bloom et al. (WO 2006/134340) disclose that peptides which bind and activate both

the glucagon and the GLP-1 receptor can be constructed as hybrid molecules from glucagon and exendin-4, where the N-terminal part (e.g. residues 1-14 or 1-24) originates from glucagon and the C-terminal part (e.g. residues 15-39 or 25-39) originates from exendin-4. Such peptides comprise glucagon's amino acid motif YSKY in positions 10-13. Krstenansky et al (Biochemistry, 1986, 25, 3833-3839) show the importance of these residues 10-13 of glucagon for its receptor interactions and activation of adenylate cyclase.

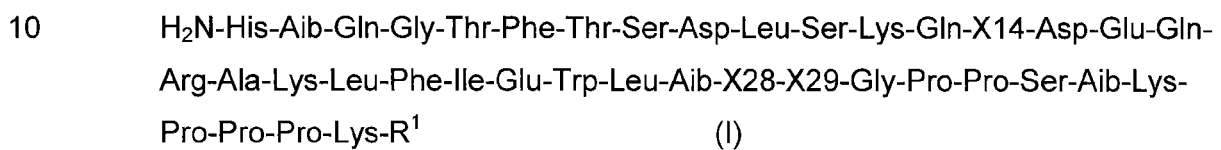
In the exendin-4 derivatives described in this invention, several of the underlying residues are different from glucagon and the peptides described in WO 2006/134340. In particular residues Tyr10 and Tyr13, which are known to contribute to the fibrillation of glucagon (JS Pedersen et al., Biochemistry, 2006, 45, 14503-14512) are replaced by Leu in position 10 and Gln, a non-aromatic polar amino acid, in position 13. This replacement, especially in combination with isoleucine in position 23 and glutamate in position 24, leads to exendin-4 derivatives with potentially improved biophysical properties as solubility or aggregation behaviour in solution. The non-conservative replacement of an aromatic amino acid with a polar amino acid in position 13 of an exendin-4 analogue leads to peptides with high activity on the glucagon receptor, keeping their activity on the GLP-1 receptor (see also WO 2013/186240 and WO 2014/056872).

## BRIEF SUMMARY OF THE INVENTION

Native exendin-4 is a pure GLP-1 receptor agonist without activity on the glucagon receptor and low activity on the GIP receptor. Provided herein are exendin-4 derivatives based on the structure of native exendin-4 but differing at fourteen or more positions as compared to SEQ ID NO: 4 wherein the differences contribute to the enhancement of the agonistic activity at the glucagon receptor. Among other substitutions - methionine at position 14 is replaced by an amino acid carrying a -NH<sub>2</sub> group in the side-chain, which is further substituted by a lipophilic residue (e.g. a fatty acid combined with a linker). Furthermore, we surprisingly found that a replacement of the exendin-4 amino acids at positions 27, 32, 34, 35 and 39 with an Aib amino acid in positions 27 and 34, Pro at position 32 and Lys at position 35 and

39 leads to reduced GIP receptor activity compared to the GLP-1 receptor activity. A reduced activation of the GIP receptor is potentially beneficial as there are reports in the literature that high levels of GIP in diabetics might in some cases lead to more frequent episodes of hypoglycemia (McLaughlin et al., J Clin Endocrinol Metab, 5 2010, 95, 1851–1855; Hadji-Georgopoulos, J Clin Endocrinol Metab, 1983, 56, 648-652).

The invention provides a peptidic compound having the formula (I):



wherein

15

X14 represents an amino acid residue with a functionalized  $-\text{NH}_2$  side chain group, selected from the group consisting of Lys, Orn, Dab, or Dap, wherein the  $-\text{NH}_2$  side chain group is functionalized by  $-\text{Z-C(O)-R}^5$ , wherein

20

Z represents a linker in all stereoisomeric forms and  $\text{R}^5$  is a moiety comprising up to 50 carbon atoms and heteroatoms selected from N and O,

X28 represents an amino acid residue selected from Ala, Lys and Ser,

X29 represents an amino acid residue selected from D-Ala and Gly,

25

$\text{R}^1$  is  $\text{NH}_2$  or OH, or a salt or solvate thereof.

The compounds of the invention are GLP-1 and glucagon receptor agonists as determined by the observation that they are capable of stimulating intracellular cAMP 30 formation in the assay system described in Methods.

According to another embodiment, the compounds of the invention, particularly with a lysine at position 14 which is further substituted with a lipophilic residue, exhibit at least a relative activity of 0.1% (i.e.  $\text{EC}_{50} < 700 \text{ pM}$ ), more preferably of 1% (i.e.  $\text{EC}_{50}$

< 70 pM), more preferably of 5% (i.e.  $EC_{50} < 14$  pM) and even more preferably of 10% (i.e.  $EC_{50} < 7$  pM) compared to that of GLP-1(7-36)amide at the GLP-1 receptor. Furthermore, the compounds exhibit at least a relative activity of 0.1% (i.e.  $EC_{50} < 500$  pM), more preferably of 0.25% (i.e.  $EC_{50} < 200$  pM) and even more preferably of 0.5% (i.e.  $EC_{50} < 100$  pM) compared to that of natural glucagon at the glucagon receptor.

In a particular embodiment, the peptidic compound has a relative activity of at least 0.09% compared to that of natural glucagon at the glucagon receptor.

10

In a further particular embodiment, the peptidic compound has a relative activity of at least 0.1% compared to that of GLP1(7-36)-amide at the GLP-1 receptor.

The term "activity" as used herein preferably refers to the capability of a compound to activate the human GLP-1 receptor and the human glucagon receptor. More preferably the term "activity" as used herein refers to the capability of a compound to stimulate intracellular cAMP formation. The term "relative activity" as used herein is understood to refer to the capability of a compound to activate a receptor in a certain ratio as compared to another receptor agonist or as compared to another receptor.

The activation of the receptors by the agonists (e.g. by measuring the cAMP level) is determined as described herein, e.g. as described in Example 5.

The compounds of the invention preferably have an  $EC_{50}$  for hGLP-1 receptor of 450 pmol or less, preferably of 200 pmol or less, more preferably of 100 pmol or less, more preferably of 50 pmol or less, more preferably of 25 pmol or less, more preferably of 10 pmol or less, more preferably of 8 pmol or less, and more preferably of 5 pmol or less and/or an  $EC_{50}$  for hGlucagon receptor of 500 pmol or less, preferably of 300 pmol or less, more preferably of 200 pmol or less, more preferably of 150 pmol or less, more preferably of 100 pmol or less, more preferably of 75 pmol or less and/or an  $EC_{50}$  for hGIP receptor of 750 pmol or more, preferably of 1500 pmol or more; more preferably of 2000 pmol or more. It is particularly preferred that the  $EC_{50}$  for both hGLP-1 and hGlucagon receptors is 250 pmol or less, more preferably of 200 pmol or less, more preferably of 150 pmol or less, more preferably of 100 pmol or less, more preferably of 75 pmol or less. The  $EC_{50}$  for the hGLP-1



receptor, the hGlucagon receptor and the hGIP receptor may be determined as described in the Methods herein and as used to generate the results described in Example 5, Table 5.

- 5 Peptidic compounds of the formula (I), particularly those with a lysine at position 14 which is further substituted with a lipophilic residue, showed increased glucagon receptor activation compared to derivatives having the original methionine (from exendin-4) or leucine at position 14 (see also WO 2014/056872). Furthermore, oxidation (in vitro or in vivo) of methionine is not possible anymore. In addition, this  
10 modification results in an improved pharmacokinetic profile.

It was surprisingly found that compounds of formula (I) carrying an Aib amino acid in positions 27 and 34, Pro at position 32 and Lys at position 35 and 39 show reduced activity on the GIP receptor compared to the corresponding derivatives with the  
15 amino acids of native exendin-4 in the corresponding positions (Lys27, Ser32, Gly34, Ala35, Ser39), as shown in Example 6, Table 6. A reduced activation of the GIP receptor is potentially beneficial as there are reports in the literature that high levels of GIP in diabetics might in some cases lead to more frequent episodes of hypoglycemia (T McLaughlin et al., J Clin Endocrinol Metab, 95, 1851–1855, 2010; A  
20 Hadji-Georgopoulos, J Clin Endocrinol Metab, 56, 648-652, 1983).

In one embodiment the compounds of the invention have a high solubility at acidic and/or physiological pH values in the presence of an antimicrobial preservative like phenol or m-cresol, e.g., at an acidity range from pH 4 to 5, especially pH 4.5 and/or  
25 a more physiological range from pH 6 to 8, especially at pH 7.4 at 25°C or 40°C, in another embodiment at least 1 mg/ml and in a particular embodiment at least 5 mg/ml.

Furthermore, the compounds of the invention preferably have a high stability when  
30 stored in solution in the presence of an antimicrobial preservative like phenol or m-cresol. Preferred assay conditions for determining the stability is storage for 7 days at 25°C or 40°C in solution at an acidity range from pH 4 to 5, especially pH 4.5 and/or a more physiological range from pH 6 to 8, especially at pH 7.4. The stability of peptide is determined by chromatographic analyses as described in the Methods.

Preferably, after 7 days at 40°C in solution at pH 4.5 or pH 7.4, the purity loss is no more than 20%, more preferably no more than 15%, even more preferably no more than 10% and even more preferably no more than 5%.

- 5 In one embodiment the compounds of the invention show a hydrodynamic diameter of 10 nm or less at concentrations of  $\geq 7$  mg/ml in the presence of an antimicrobial preservative like phenol or m-cresol, e.g., at an acidity range from pH 4 to 5, especially pH 4.5 and/or a more physiological range from pH 6 to 8, especially at pH 7.4. at 25°C as assayed by dynamic light scattering as described in Methods.

10

Compounds of this invention are more resistant to cleavage by neutral endopeptidase (NEP) and dipeptidyl peptidase-4 (DPP4), resulting in a longer half-life and duration of action in vivo, when compared with native GLP-1 and glucagon.

- 15 Preferably, the compounds of the present invention comprise a peptide moiety which is a linear sequence of 39 amino carboxylic acids, particularly  $\alpha$ -amino carboxylic acids linked by peptide, i.e. carboxamide bonds.

In one embodiment,  $R^1$  is  $NH_2$ .

20

The  $-NH_2$  side chain group at position X14 is functionalized by  $-Z-C(O)-R^5$ , wherein  $R^5$  is a moiety comprising up to 50 carbon atoms and optionally one or more heteroatoms independently selected from N and O.

- 25 Specific preferred examples for  $-Z-C(O)-R^5$  groups are listed in the following Table 2, which are selected from

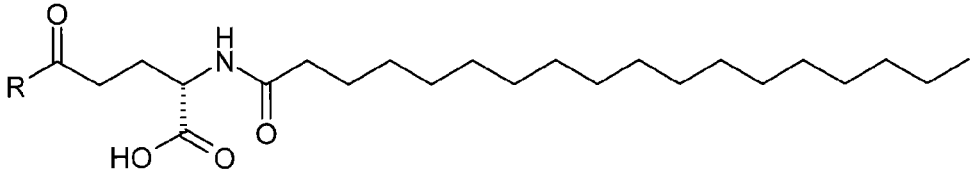
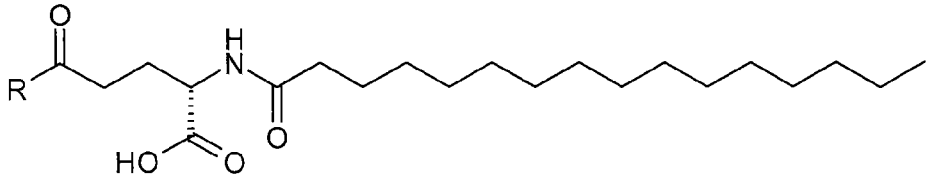
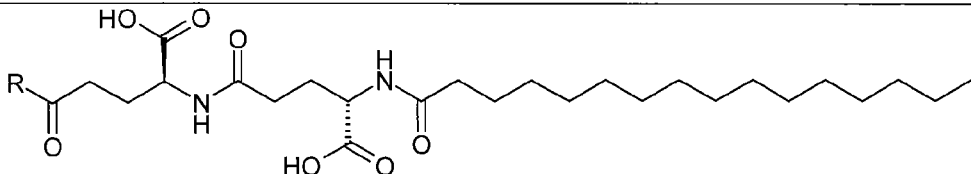
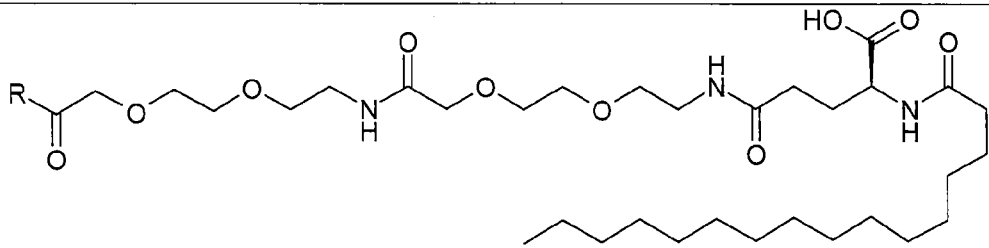
(S)-4-Carboxy-4-hexadecanoylamino-butyryl-, (S)-4-Carboxy-4-octadecanoylamino-butyryl-, (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-, (2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-hexadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-, (2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-octadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-, [2-(2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-octadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-].

30

Further preferred are stereoisomers, particularly enantiomers of these groups, either S- or R-enantiomers. The term "R" in Table 2 is intended to mean the attachment site of -Z-C(O)-R<sup>5</sup> at the peptide backbone, for example the epsilon-amino group of Lys.

5

Table 2

Structure / IUPAC	name
 <p>(S)-4-Carboxy-4-octadecanoylamino-butyryl-</p>	gGlu- Stea
 <p>(S)-4-Carboxy-4-hexadecanoylamino-butyryl-</p>	gGlu- Palm
 <p>(S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-</p>	gGlu- gGlu- Palm
 <p>(2-{2-[2-(2-{(4S)-4-Carboxy-4-hexadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-</p>	AEEAc- AEEAc- gGlu- Palm

<p>(2-{2-[2-(2-{[(4S)-4-Carboxy-4-octadecanoylamino-butrylamino]-ethoxy}-ethoxy)-acetyl-amino]-ethoxy}-ethoxy)-acetyl-</p>	<p>AEEAc- AEEAc- gGlu- Stea</p>
<p>[2-(2-{2-[2-(2-{2-[2-(2-Octadecanoylamino-ethoxy)-ethoxy]-acetyl-amino}-ethoxy)-ethoxy]-acetyl-amino}-ethoxy)-ethoxy]-acetyl-</p>	<p>AEEAc- AEEAc- AEEAc- Stea</p>

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized with a group -Z-C(O)R<sup>5</sup>, wherein

Z represents a group selected from gGlu, gGlu-gGlu, AEEAc-AEEAc-gGlu and AEEAc-AEEAc-AEEAc and

R<sup>5</sup> represents a group selected from pentadecanyl or heptadecanyl.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-octadecanoylamino-butryl-,

X28 represents an amino acid residue selected from Ala and Lys,

X29 represents Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-

4-Carboxy-4-hexadecanoylamino-butyryl-,

X28 represents Ala,

X29 represents Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

5 or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-

4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

10 X28 represents an amino acid residue selected from Ala, Ser and Lys,

X29 represents an amino acid residue selected from Gly and D-Ala,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

15 A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-

4-Carboxy-4-hexadecanoylamino-butyryl-, (S)-4-Carboxy-4-octadecanoylamino-

butyryl-, (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-

butyryl-, (2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-hexadecanoylamino-butyrylamino]-

20 ethoxy}-ethoxy)-acetyl-amino]-ethoxy}-ethoxy)-acetyl-, (2-{2-[2-(2-{2-[(4S)-4-

Carboxy-4-octadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetyl-amino]-

ethoxy}-ethoxy)-acetyl-, [2-(2-{2-[2-(2-{2-[2-(2-Octadecanoylamino-ethoxy)-

ethoxy]-acetyl-amino}-ethoxy)-ethoxy]-acetyl-amino}-ethoxy)-ethoxy]-acetyl-,

X28 represents Ala,

25 X29 represents an amino acid residue selected from D-Ala and Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

30 X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-

4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents Ser,

X29 represents an amino acid residue selected from D-Ala and Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-  
 4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-, (S)-  
 4-Carboxy-4-octadecanoylamino-butyryl-,

X28 represents Lys,

X29 represents an amino acid residue selected from D-Ala and Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-  
 4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents an amino acid residue selected from Ala, Lys and Ser,

X29 represents D-Ala,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-  
 4-Carboxy-4-hexadecanoylamino-butyryl-, (S)-4-Carboxy-4-octadecanoylamino-  
 butyryl-, (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-  
 butyryl-, (2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-hexadecanoylamino-butyrylamino]-  
 ethoxy}-ethoxy)-acetyl]-ethoxy}-ethoxy)-acetyl-, (2-{2-[2-(2-{2-[(4S)-4-  
 Carboxy-4-octadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetyl]-ethoxy}-  
 ethoxy)-acetyl-, [2-(2-{2-[2-(2-{2-[(2-Octadecanoylamino-ethoxy)-  
 ethoxy]-acetyl]-ethoxy}-ethoxy)-acetyl]-ethoxy)-ethoxy]-acetyl-,

X28 represents an amino acid residue selected from Ala, Lys and Ser,

X29 represents Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents Ala,

X29 represents an amino acid residue selected from Gly and D-Ala,

5 R<sup>1</sup> represents NH<sub>2</sub>,  
or a salt or solvate thereof.

A further embodiment relates to a group of compounds of formula (I), wherein

10 X14 represents Lys, wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-hexadecanoylamino-butyryl-, (S)-4-Carboxy-4-octadecanoylamino-butyryl-, (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,  
or a salt or solvate thereof.

15 A still further embodiment relates to a group of compounds of formula (I), wherein  
X14 represents Lys, wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,  
or a salt or solvate thereof.

20 Specific examples of peptidic compounds of formula (I) are the compounds of SEQ ID NO: 6-17, as well as salts or solvates thereof.

Specific examples of peptidic compounds of formula (I) are the compounds of SEQ ID NO: 6 and 7 as well as salts or solvates thereof.

25 According to one particular embodiment, the compound of the invention is represented by SEQ ID NO.: 6, or a salt or solvate thereof.

30 According to another particular embodiment, the compound of the invention is represented by SEQ ID NO.: 7, or a salt or solvate thereof.

According to another particular embodiment, the compound of the invention is represented by SEQ ID NO.: 8, or a salt or solvate thereof.

According to another particular embodiment, the compound of the invention is represented by SEQ ID NO.: 9, or a salt or solvate thereof.

5 According to another particular embodiment, the compound of the invention is represented by SEQ ID NO.: 10, or a salt or solvate thereof.

According to another particular embodiment, the compound of the invention is represented by SEQ ID NO.: 11, or a salt or solvate thereof.

10 According to another particular embodiment, the compound of the invention is represented by SEQ ID NO.: 15, or a salt or solvate thereof.

In certain embodiments, i.e. when the compound of formula (I) comprises genetically encoded amino acid residues, the invention further provides a nucleic acid (which  
15 may be DNA or RNA) encoding said compound, an expression vector comprising such a nucleic acid, and a host cell containing such a nucleic acid or expression vector.

In a further aspect, the present invention provides a compound of formula (I) for use  
20 in medicine, particularly human medicine. In certain embodiments, the compound of formula (I) is for use as a pharmaceutical.

In a further aspect, the present invention provides a composition comprising a compound of the invention in admixture with a carrier. In preferred embodiments, the  
25 composition is a pharmaceutically acceptable composition and the carrier is a pharmaceutically acceptable carrier. The compound of the invention may be in the form of a salt, e.g. a pharmaceutically acceptable salt or a solvate, e.g. a hydrate. In still a further aspect, the present invention provides a composition for use in a method of medical treatment, particularly in human medicine.

30

In certain embodiments, the nucleic acid or the expression vector may be used as therapeutic agents, e.g. in gene therapy.

The compounds of formula (I) are suitable for therapeutic application without an



additional therapeutically effective agent. In other embodiments, however, the compounds may be used together with at least one additional therapeutically active agent, as described in "combination therapy".

- 5 The compounds of formula (I) are particularly suitable for the treatment or prevention of diseases or disorders caused by, associated with and/or accompanied by disturbances in carbohydrate and/or lipid metabolism, e.g. for the treatment or prevention of hyperglycemia, type 2 diabetes, impaired glucose tolerance, type 1 diabetes, obesity and metabolic syndrome. Further, the compounds of the invention  
10 are particularly suitable for the treatment or prevention of degenerative diseases, particularly neurodegenerative diseases.

The compounds described find use, inter alia, in preventing weight gain or promoting weight loss. By "preventing" is meant inhibiting or reducing when compared to the  
15 absence of treatment, and is not necessarily meant to imply complete cessation of a disorder.

The compounds of the invention may cause a decrease in food intake and/or increase in energy expenditure, resulting in the observed effect on body weight.  
20

Independently of their effect on body weight, the compounds of the invention may have a beneficial effect on circulating cholesterol levels, being capable of improving lipid levels, particularly LDL, as well as HDL levels (e.g. increasing HDL/LDL ratio).

- 25 Thus, the compounds of the invention can be used for direct or indirect therapy of any condition caused or characterised by excess body weight, such as the treatment and/or prevention of obesity, morbid obesity, obesity linked inflammation, obesity linked gallbladder disease, obesity induced sleep apnea. They may also be used for treatment and prevention of the metabolic syndrome, diabetes, hypertension,  
30 atherogenic dyslipidemia, atherosclerosis, arteriosclerosis, coronary heart disease, or stroke. Their effects in these conditions may be as a result of or associated with their effect on body weight, or may be independent thereof.

Preferred medical uses include delaying or preventing disease progression in type 2

diabetes, treating metabolic syndrome, treating obesity or preventing overweight, for decreasing food intake, increase energy expenditure, reducing body weight, delaying the progression from impaired glucose tolerance (IGT) to type 2 diabetes; delaying the progression from type 2 diabetes to insulin-requiring diabetes; regulating

5 appetite; inducing satiety; preventing weight regain after successful weight loss; treating a disease or state related to overweight or obesity; treating bulimia; treating binge eating; treating atherosclerosis, hypertension, type 2 diabetes, IGT, dyslipidemia, coronary heart disease, hepatic steatosis, treatment of beta-blocker poisoning, use for inhibition of the motility of the gastrointestinal tract.

10

Further, the compounds are useful in connection with investigations of the gastrointestinal tract using techniques such as X-ray, CT- and NMR-scanning.

Further preferred medical uses include treatment or prevention of degenerative

15 disorders, particularly neurodegenerative disorders such as Alzheimer's disease, Parkinson's disease, Huntington's disease, ataxia, e.g. spinocerebellar ataxia, Kennedy disease, myotonic dystrophy, Lewy body dementia, multi-systemic atrophy, amyotrophic lateral sclerosis, primary lateral sclerosis, spinal muscular atrophy, prion-associated diseases, e.g. Creutzfeldt-Jacob disease, multiple sclerosis,

20 telangiectasia, Batten disease, corticobasal degeneration, subacute combined degeneration of spinal cord, Tabes dorsalis, Tay-Sachs disease, toxic encephalopathy, infantile Refsum disease, Refsum disease, neuroacanthocytosis, Niemann-Pick disease, Lyme disease, Machado-Joseph disease, Sandhoff disease, Shy-Drager syndrome, wobbly hedgehog syndrome, proteopathy, cerebral  $\beta$ -amyloid

25 angiopathy, retinal ganglion cell degeneration in glaucoma, synucleinopathies, tauopathies, frontotemporal lobar degeneration (FTLD), dementia, cadasil syndrome, hereditary cerebral hemorrhage with amyloidosis, Alexander disease, serpinopathies, familial amyloidotic neuropathy, senile systemic amyloidosis, serpinopathies, AL (light chain) amyloidosis (primary systemic amyloidosis), AH (heavy chain) amyloidosis, AA

30 (secondary) amyloidosis, aortic medial amyloidosis, ApoA1 amyloidosis, ApoAII amyloidosis, ApoAIV amyloidosis, familial amyloidosis of the Finnish type (FAF), Lysozyme amyloidosis, Fibrinogen amyloidosis, Dialysis amyloidosis, Inclusion body myositis/myopathy, Cataracts, Retinitis pigmentosa with rhodopsin mutations, medullary thyroid carcinoma, cardiac atrial amyloidosis, pituitary prolactinoma,

Hereditary lattice corneal dystrophy, Cutaneous lichen amyloidosis, Mallory bodies, corneal lactoferrin amyloidosis, pulmonary alveolar proteinosis, odontogenic (Pindborg) tumor amyloid, cystic fibrosis, sickle cell disease or critical illness myopathy (CIM).

5

## DETAILED DESCRIPTION OF THE INVENTION

### Definitions

10 The amino acid sequences of the present invention contain the conventional one letter and three letter codes for naturally occurring amino acids, as well as generally accepted three letter codes for other amino acids, such as Aib ( $\alpha$ -aminoisobutyric acid).

15 The term „native exendin-4“ refers to native exendin-4 having the sequence HGEFTFTSDLSKQMEEEEAVRLFIEWLKNGGPSSGAPPPS-NH<sub>2</sub> (SEQ ID NO: 4).

The invention provides peptidic compounds as defined above.

20 The peptidic compounds of the present invention comprise a linear backbone of amino carboxylic acids linked by peptide, i.e. carboxamide bonds. Preferably, the amino carboxylic acids are  $\alpha$ -amino carboxylic acids and more preferably L- $\alpha$ -amino carboxylic acids, unless indicated otherwise. The peptidic compounds preferably comprise a backbone sequence of 39 amino carboxylic acids.

25

For the avoidance of doubt, in the definitions provided herein, it is generally intended that the sequence of the peptidic moiety (formula I) differs from native exendin-4 at least at fourteen of those positions which are stated to allow variation. Amino acids within the peptide moiety (formula I) can be considered to be numbered

30 consecutively from 1 to 39 in the conventional N-terminal to C-terminal direction.

Reference to a „position“ within peptidic moiety (I) should be constructed accordingly, as should reference to positions within native exendin-4 and other molecules, e.g., in exendin-4, His is at position 1, Gly at position 2, ..., Met at position 14, ... and Ser at position 39.

An amino acid residue with an -NH<sub>2</sub> side chain group, e.g. Lys, Orn, Dab or Dap, is functionalized in that at least one H atom of the -NH<sub>2</sub> side chain group is replaced by -Z-C(O)-R<sup>5</sup>, wherein R<sup>5</sup> comprises a lipophilic moiety, e.g. an acyclic linear or

- 5 branched (C<sub>8</sub>-C<sub>30</sub>) saturated or unsaturated hydrocarbon group, which is unsubstituted or substituted e.g. by halogen (F, Cl, Br, J), -OH and/or CO<sub>2</sub>H and Z comprises a linker in all stereoisomeric forms, e.g. a linker comprising one or more, e.g. 1 to 5, preferably 1, 2 or 3 amino acid linker groups selected from the group gamma-Glutamate (gGlu) and AEEAc (amino-ethoxy-ethoxy-acetyl). Preferred
- 10 groups R<sup>5</sup> comprise a lipophilic moiety, e.g. an acyclic linear or branched (C<sub>12</sub>-C<sub>20</sub>) saturated or unsaturated hydrocarbon group, e.g. pentadecanyl, hexadecanyl or heptadecanyl, which is unsubstituted or substituted by CO<sub>2</sub>H, more preferably pentadecanyl, or heptadecanyl. In one embodiment amino acid linker groups are selected from gGlu, gGlu-gGlu, AEEAc-AEEAc-gGlu and AEEAc-AEEAc-AEEAc. In
- 15 another embodiment the amino acid linker group is gGlu. In another embodiment the amino acid linker group is gGlu-gGlu. In another embodiment the amino acid linker group is AEEAc-AEEAc-gGlu. In another embodiment the amino acid linker group is AEEAc-AEEAc-AEEAc.

- 20 In a further aspect, the present invention provides a composition comprising a compound of the invention as described herein, or a salt or solvate thereof, in admixture with a carrier.

- 25 The invention also provides the use of a compound of the present invention for use as a medicament, particularly for the treatment of a condition as described in the specification.

- The invention further provides a method for treating a condition as described herein, the method comprising administering to the patient an effective amount of at least
- 30 one compound of formula (I).

The invention also provides a composition wherein the composition is a pharmaceutically acceptable composition, and the carrier is a pharmaceutically acceptable carrier.

### Peptide synthesis

The skilled person is aware of a variety of different methods to prepare peptides that are described in this invention. These methods include but are not limited to synthetic approaches and recombinant gene expression. Thus, one way of preparing these peptides is the synthesis in solution or on a solid support and subsequent isolation and purification. A different way of preparing the peptides is gene expression in a host cell in which a DNA sequence encoding the peptide has been introduced.

Alternatively, the gene expression can be achieved without utilizing a cell system. The methods described above may also be combined in any way.

A preferred way to prepare the peptides of the present invention is solid phase synthesis on a suitable resin. Solid phase peptide synthesis is a well-established methodology (see for example: Stewart and Young, Solid Phase Peptide Synthesis, Pierce Chemical Co., Rockford, Ill., 1984; E. Atherton and R. C. Sheppard, Solid Phase Peptide Synthesis. A Practical Approach, Oxford-IRL Press, New York, 1989). Solid phase synthesis is initiated by attaching an N-terminally protected amino acid with its carboxy terminus to an inert solid support carrying a cleavable linker. This solid support can be any polymer that allows coupling of the initial amino acid, e.g. a trityl resin, a chlorotriyl resin, a Wang resin or a Rink resin in which the linkage of the carboxy group (or carboxamide for Rink resin) to the resin is sensitive to acid (when Fmoc strategy is used). The polymer support must be stable under the conditions used to deprotect the  $\alpha$ -amino group during the peptide synthesis.

After the N-terminally protected first amino acid has been coupled to the solid support, the  $\alpha$ -amino protecting group of this amino acid is removed. The remaining protected amino acids are then coupled one after the other or with a preformed dipeptide, tripeptide or tetrapeptide in the order represented by the peptide sequence using appropriate amide coupling reagents, for example BOP, HBTU, HATU or DIC (N,N'-diisopropylcarbodiimide) / HOBt (1-hydroxybenzotriazole), wherein BOP, HBTU and HATU are used with tertiary amine bases. Alternatively, the liberated N-terminus can be functionalized with groups other than amino acids, for example carboxylic acids, etc.

Usually, reactive side-chain groups of the amino acids are protected with suitable blocking groups. These protecting groups are removed after the desired peptides have been assembled. They are removed concomitantly with the cleavage of the desired product from the resin under the same conditions. Protecting groups and the procedures to introduce protecting groups can be found in Protective Groups in Organic Synthesis, 3d ed., Greene, T. W. and Wuts, P. G. M., Wiley & Sons (New York: 1999).

In some cases it might be desirable to have side-chain protecting groups that can selectively be removed while other side-chain protecting groups remain intact. In this case the liberated functionality can be selectively functionalized. For example, a lysine may be protected with an ivDde ([1-(4,4-dimethyl-2,6-dioxocyclohex-1-ylidene)-3-methylbutyl) protecting group (S.R. Chhabra et al., Tetrahedron Lett. 39, (1998), 1603) which is labile to a very nucleophilic base, for example 4% hydrazine in DMF (dimethyl formamide). Thus, if the N-terminal amino group and all side-chain functionalities are protected with acid labile protecting groups, the ivDde group can be selectively removed using 4% hydrazine in DMF and the corresponding free amino group can then be further modified, e.g. by acylation. The lysine can alternatively be coupled to a protected amino acid and the amino group of this amino acid can then be deprotected resulting in another free amino group which can be acylated or attached to further amino acids. Alternatively, the side chain (as described in table 2) can be introduced together with the lysine during peptide synthesis using the a prefunctionalized building block, e.g. (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid, as coupling partner. The use of this building block has the technical advantage that no selective deprotection step is necessary and that selective attachment of the side chain building blocks on a very advanced synthesis intermediate can be avoided.

Finally the peptide is cleaved from the resin. This can be achieved by using King's cocktail (D. S. King, C. G. Fields, G. B. Fields, Int. J. Peptide Protein Res. 36, 1990, 255-266). The raw material can then be purified by chromatography, e.g. preparative RP-HPLC, if necessary.

### Potency

As used herein, the term “potency” or “in vitro potency” is a measure for the ability of a compound to activate the receptors for GLP-1, glucagon or GIP in a cell-based assay. Numerically, it is expressed as the “EC50 value”, which is the effective concentration of a compound that induces a half maximal increase of response (e.g. formation of intracellular cAMP) in a dose-response experiment.

### 10 Therapeutic uses

Metabolic syndrome is a combination of medical disorders that, when occurring together, increase the risk of developing type 2 diabetes, as well as atherosclerotic vascular disease, e.g. heart disease and stroke. Defining medical parameters for the metabolic syndrome include diabetes mellitus, impaired glucose tolerance, raised fasting glucose, insulin resistance, urinary albumin secretion, central obesity, hypertension, elevated triglycerides, elevated LDL cholesterol and reduced HDL cholesterol.

20 Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have an adverse effect on health and life expectancy and due to its increasing prevalence in adults and children it has become one of the leading preventable causes of death in modern world. It increases the likelihood of various other diseases, including heart disease, type 2 diabetes, obstructive sleep apnoea, certain types of cancer, as well as osteoarthritis, and it is most commonly caused by a combination of excess food intake, reduced energy expenditure, as well as genetic susceptibility.

30 Diabetes mellitus, often simply called diabetes, is a group of metabolic diseases in which a person has high blood sugar levels, either because the body does not produce enough insulin, or because cells do not respond to the insulin that is produced. The most common types of diabetes are: (1) type 1 diabetes, where the body fails to produce insulin; (2) type 2 diabetes (T2DM), where the body fails to use insulin properly, combined with an increase in insulin deficiency over time, and (3)

gestational diabetes, where women develop diabetes due to their pregnancy. All forms of diabetes increase the risk of long-term complications, which typically develop after many years. Most of these long-term complications are based on damage to blood vessels and can be divided into the two categories “macrovascular” disease, arising from atherosclerosis of larger blood vessels and “microvascular” disease, arising from damage of small blood vessels. Examples for macrovascular disease conditions are ischemic heart disease, myocardial infarction, stroke and peripheral vascular disease. Examples for microvascular diseases are diabetic retinopathy, diabetic nephropathy, as well as diabetic neuropathy.

10

The receptors for GLP-1 and GIP as well as glucagon are members of the family of 7-transmembrane-spanning, heterotrimeric G-protein coupled receptors. They are structurally related to each other and share not only a significant level of sequence identity, but have also similar mechanisms of ligand recognition and intracellular signaling pathways.

15

Similarly, the peptides GLP-1, GIP and glucagon share regions of high sequence identity/similarity. GLP-1 and glucagon are produced from a common precursor, proglucagon, which is differentially processed in a tissue-specific manner to yield e.g. GLP-1 in intestinal endocrine cells and glucagon in alpha cells of pancreatic islets. GIP is derived from a larger proGIP prohormone precursor and is synthesized and released from K-cells located in the small intestine.

20

The peptidic incretin hormones GLP-1 and GIP are secreted by intestinal endocrine cells in response to food and account for up to 70% of meal-stimulated insulin secretion. Evidence suggests that GLP-1 secretion is reduced in subjects with impaired glucose tolerance or type 2 diabetes, whereas responsiveness to GLP-1 is still preserved in these patients. Thus, targeting of the GLP-1 receptor with suitable agonists offers an attractive approach for treatment of metabolic disorders, including diabetes. The receptor for GLP-1 is distributed widely, being found mainly in pancreatic islets, brain, heart, kidney and the gastrointestinal tract. In the pancreas, GLP-1 acts in a strictly glucose-dependent manner by increasing secretion of insulin from beta cells. This glucose-dependency shows that activation of GLP-1 receptors is unlikely to cause hypoglycemia. Also the receptor for GIP is broadly expressed in

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peripheral tissues including pancreatic islets, adipose tissue, stomach, small intestine, heart, bone, lung, kidney, testis, adrenal cortex, pituitary, endothelial cells, trachea, spleen, thymus, thyroid and brain. Consistent with its biological function as incretin hormone, the pancreatic  $\beta$ -cell express the highest levels of the receptor for

5 GIP in humans. There is some clinical evidence that the GIP-receptor mediated signaling could be impaired in patients with T2DM but GIP-action is shown to be reversible and can be restored with improvement of the diabetic status. While there are many reports that also GIP action on insulin secretion is glucose-dependent, there are also reports in the literature that high plasma levels of GIP might lead to  
10 more frequent episodes of hypoglycemia (McLaughlin et al., J Clin Endocrinol 1983, 56, 648-652). In addition, plasma GIP levels in obese subjects were reported to be higher than normal, suggesting that GIP might induce obesity and insulin resistance (Creutzfeldt et al., Diabetologia. 1978, 14,15-24). This is supported by reports that the ablation of the GIP receptor might prevent those conditions: GIP receptor knock-  
15 out mice fed on high-fat diet actually showed a suppression of body weight compared to wild-type mice (Miyawaki et al., Nat Med. 2002, 8, 738-42), and long-term administration of the GIP receptor antagonist (Pro3)GIP also prevented obesity and insulin resistance in mice (Gault et al., Diabetologia. 2007, 50,1752-62). Therefore, goal of this invention was to provide dual GLP-1/glucagon receptor agonists with  
20 reduced activity on the GIP receptor.

Glucagon is a 29 amino acid peptide hormone that is produced by pancreatic alpha cells and released into the bloodstream when circulating glucose is low. An important physiological role of glucagon is to stimulate glucose output in the liver, which is a  
25 process providing the major counterregulatory mechanism for insulin in maintaining glucose homeostasis in vivo.

Glucagon receptors are however also expressed in extra-hepatic tissues such as kidney, heart, adipocytes, lymphoblasts, brain, retina, adrenal gland and  
30 gastrointestinal tract, suggesting a broader physiological role beyond glucose homeostasis. Accordingly, recent studies have reported that glucagon has therapeutically positive effects on energy management, including stimulation of energy expenditure and thermogenesis, accompanied by reduction of food intake and body weight loss. Altogether, stimulation of glucagon receptors might be useful in

the treatment of obesity and the metabolic syndrome.

Oxyntomodulin is a peptide hormone consisting of glucagon with an eight amino acids encompassing C-terminal extension. Like GLP-1 and glucagon, it is pre-formed in preproglucagon and cleaved and secreted in a tissue-specific manner by endocrinal cells of the small bowel. Oxyntomodulin is known to stimulate both, the receptors for GLP-1 and glucagon and is therefore the prototype of a dual agonist (see Pocai, Molecular Metabolism 2013; 3:241-51).

As GLP-1 is known for its anti-diabetic effects, GLP-1 and glucagon are both known for their food intake-suppressing effects and glucagon is also a mediator of additional energy expenditure, it is conceivable that a combination of the activities of the two hormones in one molecule can yield a powerful medication for treatment of the metabolic syndrome and in particular its components diabetes and obesity.

15

Accordingly, the compounds of the invention may be used for treatment of glucose intolerance, insulin resistance, pre-diabetes, increased fasting glucose (hyperglycemia), type 2 diabetes, hypertension, dyslipidemia, arteriosclerosis, coronary heart disease, peripheral artery disease, stroke or any combination of these individual disease components.

20

In addition, they may be used for control of appetite, feeding and calory intake, increase of energy expenditure, prevention of weight gain, promotion of weight loss, reduction of excess body weight and altogether treatment of obesity, including morbid obesity.

25

The compounds of the invention are agonists for the receptors for GLP-1 and for glucagon (e.g. "dual agonists") with reduced activity on the GIP receptor and may provide therapeutic benefit to address a clinical need for targeting the metabolic syndrome by allowing simultaneous treatment of diabetes and obesity.

30

Further disease states and health conditions which could be treated with the compounds of the invention are obesity-linked inflammation, obesity-linked gallbladder disease and obesity-induced sleep apnea.

Although all these conditions could be associated directly or indirectly with obesity, the effects of the compounds of the invention may be mediated in whole or in part via an effect on body weight, or independent thereof.

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Further, diseases to be treated are neurodegenerative diseases such as Alzheimer's disease or Parkinson's disease, or other degenerative diseases as described above.

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In one embodiment the compounds are useful in the treatment or prevention of hyperglycemia, type 2 diabetes, obesity. In one preferred embodiment, the compounds are useful in the treatment of diabetes, particularly type 2 diabetes mellitus.

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The compounds of the invention have the ability to reduce the intestinal passage, increase the gastric content and/or to reduce the food intake of a patient. These activities of the compounds of the invention can be assessed in animal models known to the skilled person and also described herein in the Methods.

20

The compounds of the invention have the ability to reduce blood glucose level, and/or to reduce HbA1c levels of a patient. These activities of the compounds of the invention can be assessed in animal models known to the skilled person and also described herein in the Methods and in Example 7.

25

The compounds of the invention have the ability to reduce body weight of a patient. These activities of the compounds of the invention can be assessed in animal models known to the skilled person and also described herein in the Methods and in Example 7.

30

The compounds of the invention are useful in the treatment or prevention of hepatosteatosi, preferably non-alcoholic liver-disease (NAFLD) and non-alcoholic steatohepatitis (NASH).

Compared to GLP-1, glucagon and oxyntomodulin, exendin-4 has beneficial physicochemical properties, such as solubility and stability in solution and under

physiological conditions (including enzymatic stability towards degradation by enzymes, such as DPP4 or NEP), which results in a longer duration of action in vivo. Therefore, the pure GLP-1 receptor agonist exendin-4 might serve as good starting scaffold to obtain exendin-4 analogues with dual GLP-1/glucagon receptor agonism.

5

Nevertheless, also exendin-4 has been shown to be chemically labile due to methionine oxidation in position 14 as well as deamidation and isomerization of asparagine in position 28. Therefore, stability might be further improved by substitution of methionine at position 14 and the avoidance of sequences that are known to be prone to degradation via aspartimide formation, especially Asp-Gly or Asn-Gly at positions 28 and 29.

10

#### Pharmaceutical compositions

15

The term "pharmaceutical composition" indicates a mixture containing ingredients that are compatible when mixed and which may be administered. A pharmaceutical composition may include one or more medicinal drugs. Additionally, the pharmaceutical composition may include carriers, buffers, acidifying agents, alkalizing agents, solvents, adjuvants, tonicity adjusters, emollients, expanders, preservatives, physical and chemical stabilizers e.g. surfactants, antioxidants and other components, whether these are considered active or inactive ingredients.

20

Guidance for the skilled in preparing pharmaceutical compositions may be found, for example, in Remington: The Science and Practice of Pharmacy, (20th ed.) ed. A. R. Gennaro A. R., 2000, Lippencott Williams & Wilkins and in R.C.Rowe et al (Ed), Handbook of Pharmaceutical Excipients, PhP, May 2013 update.

25

According to certain embodiments of the present invention, a pharmaceutical composition is provided, which comprises at least one compound of formula (I) or a physiologically acceptable salt or solvate of any of them.

30

The exendin-4 peptide derivatives of the present invention, or salts thereof, are administered in conjunction with an acceptable pharmaceutical carrier, diluent, or excipient as part of a pharmaceutical composition. Also encompassed are solvates of

the compounds of general formula (I) in conjunction with an acceptable pharmaceutical carrier, diluent, or excipient as part of a pharmaceutical composition.

A "pharmaceutically acceptable carrier" is a carrier which is physiologically acceptable (e.g. physiologically acceptable pH) while retaining the therapeutic properties of the substance with which it is administered. Standard acceptable pharmaceutical carriers and their formulations are known to one skilled in the art and described, for example, in Remington: The Science and Practice of Pharmacy, (20th ed.) ed. A. R. Gennaro A. R., 2000, Lippencott Williams & Wilkins and in R.C.Rowe et al (Ed), Handbook of Pharmaceutical excipients, PhP, May 2013 update. One exemplary pharmaceutically acceptable carrier is physiological saline solution.

In one embodiment carriers are selected from the group of buffers (e.g. citrate/citric acid), acidifying agents (e.g. hydrochloric acid), alkalizing agents (e.g. sodium hydroxide), preservatives (e.g. phenol, m-cresol), co-solvents (e.g. polyethylene glycol 400), tonicity adjusters (e.g. mannitol), stabilizers (e.g. surfactant, antioxidants, amino acids).

Concentrations used are in a range that is physiologically acceptable.

Acceptable pharmaceutical carriers or diluents include those used in formulations suitable for oral, rectal, nasal or parenteral (including subcutaneous, intramuscular, intravenous, intradermal, and transdermal) administration. The compounds of the present invention will typically be administered parenterally.

The term "pharmaceutically acceptable salt" means salts of the compounds of the invention which are safe and effective for use in mammals. Pharmaceutically acceptable salts may include, but are not limited to, acid addition salts and basic salts. Examples of acid addition salts include chloride, sulfate, hydrogen sulfate, (hydrogen) phosphate, acetate, citrate, tosylate or mesylate salts, preferably acetate. Examples of basic salts include salts with inorganic cations, e.g. alkaline or alkaline earth metal salts such as sodium, potassium, magnesium or calcium salts and salts with organic cations such as amine salts. Further examples of pharmaceutically acceptable salts are described in Remington: The Science and Practice of Pharmacy,

(20th ed.) ed. A. R. Gennaro A. R., 2000, Lippencott Williams & Wilkins or in Handbook of Pharmaceutical Salts, Properties, Selection and Use, e.d. P. H. Stahl, C. G. Wermuth, 2002, jointly published by Verlag Helvetica Chimica Acta, Zurich, Switzerland, and Wiley-VCH, Weinheim, Germany.

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The term "solvate" means complexes of the compounds of the invention or salts thereof with solvent molecules, e.g. organic solvent molecules and/or water.

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In the pharmaceutical composition, the exendin-4 derivative can be in monomeric or oligomeric form.

15

The term "therapeutically effective amount" of a compound refers to a nontoxic but sufficient amount of the compound to provide the desired effect. The amount of a compound of the formula (I) necessary to achieve the desired biological effect depends on a number of factors, for example the specific compound chosen, the intended use, the mode of administration and the clinical condition of the patient. An appropriate "effective" amount in any individual case may be determined by one of ordinary skill in the art using routine experimentation. For example the "therapeutically effective amount" of a compound of the formula (I) is about 0.01 to 50 mg/dose, preferably 0.02 to 1 mg/dose.

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Pharmaceutical compositions of the invention are those suitable for parenteral (for example subcutaneous, intramuscular, intradermal or intravenous), rectal, topical and peroral (for example sublingual) administration, although the most suitable mode of administration depends in each individual case on the nature and severity of the condition to be treated and on the nature of the compound of formula (I) used in each case. In one embodiment, application is parenteral, e.g. subcutaneous.

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In case of parenteral application, it could be favorable for the corresponding formulations to include at least one antimicrobial preservative in order to inhibit the growth of microbes and bacteria between administrations. Preferred preservatives are benzylic alcohol or phenolic compounds like phenol or m-cresol. It has been described that these ingredients can induce aggregation for peptides and proteins leading to lower solubility and stability in the formulation (see R. L. Bis et al., Int. J.

Pharm. 472, 356–361, 2014; T. J. Kamerzell, Adv. Drug Deliv. Rev., 63, 1118-1159, 2011).

Suitable pharmaceutical compositions may be in the form of separate units, for example capsules, tablets and powders in vials or ampoules, each of which contains a defined amount of the compound; as powders or granules; as solution or suspension in an aqueous or non-aqueous liquid; or as an oil-in-water or water-in-oil emulsion. It may be provided in single or multiple dose injectable form, for example in the form of a pen. The compositions may, as already mentioned, be prepared by any suitable pharmaceutical method which includes a step in which the active ingredient and the carrier (which may consist of one or more additional ingredients) are brought into contact.

In certain embodiments the pharmaceutical composition may be provided together with a device for application, for example together with a syringe, an injection pen or an autoinjector. Such devices may be provided separate from a pharmaceutical composition or prefilled with the pharmaceutical composition.

#### Combination therapy

The compounds of the present invention, dual agonists for the GLP-1 and glucagon receptors, can be widely combined with other pharmacologically active compounds, such as all drugs mentioned in the Rote Liste 2015, e.g. with all weight-reducing agents or appetite suppressants mentioned in the Rote Liste 2015, chapter 1, all lipid-lowering agents mentioned in the Rote Liste 2015, chapter 58, all antihypertensives and nephroprotectives, mentioned in the Rote Liste 2015, or all diuretics mentioned in the Rote Liste 2015, chapter 36.

The active ingredient combinations can be used especially for a synergistic improvement in action. They can be applied either by separate administration of the active ingredients to the patient or in the form of combination products in which a plurality of active ingredients are present in one pharmaceutical preparation. When the active ingredients are administered by separate administration of the active ingredients, this can be done simultaneously or successively.

Most of the active ingredients mentioned hereinafter are disclosed in the USP Dictionary of USAN and International Drug Names, US Pharmacopeia, Rockville 2011.

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Other active substances which are suitable for such combinations include in particular those which for example potentiate the therapeutic effect of one or more active substances with respect to one of the indications mentioned and/or which allow the dosage of one or more active substances to be reduced.

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Thus, in certain embodiments, the invention relates to a combination of a peptidic compound of formula (I) with at least one additional therapeutically active agent.

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Certain embodiments are directed to a pharmaceutical composition comprising at least one compound of formula (I) or a physiological acceptable salt or solvate of any of them and at least one additional pharmaceutically active ingredient.

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Therapeutic agents which are suitable for combinations with compounds of formula (I) of the present invention include, for example, antidiabetic agents such as:

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insulin and insulin derivatives (insulinic compounds), for example: glargine / Lantus<sup>®</sup>, 270 - 330U/mL of insulin glargine (EP 2387989 A), 300U/mL of insulin glargine (Toujeo<sup>®</sup>; EP 2387989 A), <sup>LAPS</sup>Insulin-115, glulisin / Apidra<sup>®</sup>, detemir / Levemir<sup>®</sup>, lispro / Humalog<sup>®</sup> / Liprolog<sup>®</sup>, degludec / degludecPlus, aspart, basal insulin and analogues (e.g. LY-2605541, LY2963016, NN1436), PEGylated insulin lispro, Humulin<sup>®</sup>, Linjeta, SuliXen<sup>®</sup>, NN1045, insulin plus symlin, PE0139, fast-acting and short-acting insulins (e.g. Linjeta, PH20, NN1218, HinsBet), (APC-002)hydrogel, oral, inhalable, transdermal and sublingual insulins (e.g. Exubera<sup>®</sup>, Nasulin<sup>®</sup>, Afrezza, tregopil, TPM 02, Capsulin, Oral-lyn<sup>®</sup>, Cobalamin<sup>®</sup> oral insulin, ORMD-0801, NN1953, NN1954, NN1956, VIAtab, Oshadi oral insulin). Additionally included are also those insulin derivatives which are bonded to albumin or another protein by a bifunctional linker.

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GLP-1, GLP-1 analogues and GLP-1 receptor agonists, for example: lixisenatide /



AVE0010 / ZP10 / lyxumia, exenatide / exendin-4 / Byetta / Bydureon / ITCA 650 / AC-2993, liraglutide / Victoza, semaglutide, taspoglutide, syncria / albiglutide, dulaglutide, rExendin-4 (recombinant exendin-4), CJC-1134-PC, PB-1023, TTP-054, efpeglenatide / HM-11260C, CM-3, GLP-1 Eligen, ORMD-0901, NN-9924, NN-9926, NN-9927, nodexen, Viador-GLP-1, CVX-096, ZYOG-1, ZYD-1, GSK-2374697, DA-3091, MAR-701, MAR709, ZP-2929, ZP-3022, TT-401, BHM-034. MOD-6030, CAM-2036, DA-15864, ARI-2651, ARI-2255, exenatide-XTEN (xtenylated exenatide) and Glucagon-Xten (xtenylated glucagon). The GLP-1 and GLP-1 analogues may optionally also be bound to a polymer.

DPP-4 (also referred to as DDP-IV or dipeptidylpeptidase IV) inhibitors, for example: alogliptin / Nesina, Trajenta / linagliptin / BI-1356 / Ondero / Trajenta / Tradjenta / Trayenta / Tradzenta, Saxagliptin / Onglyza, sitagliptin / Januvia / Xelevia / Tesave / Janumet / Velmetia, Galvus / vildagliptin, anagliptin, gemigliptin, teneligliptin, melogliptin, trelagliptin, DA-1229, omarigliptin / MK-3102, KM-223, evogliptin, ARI-2243, PBL-1427, pinoxacin.

SGLT2 (sodium glucose transporter 2) inhibitors, for example: Invokana / canagliflozin, Forxiga / dapagliflozin, remogliflozin, sergliflozin, empagliflozin, ipragliflozin, tofogliflozin, luseogliflozin, LX-4211, ertugliflozin / PF-04971729, RO-4998452, EGT-0001442, KGA-3235 / DSP-3235, LIK066, SBM-TFC-039; dual SGLT2/SGLT1 inhibitors;

biguanides (e.g. metformin, buformin, phenformin), thiazolidinediones (e.g. pioglitazone, rivoglitazone, rosiglitazone, troglitazone), dual PPAR agonists (e.g. aleglitazar, muraglitazar, tesaglitazar), sulfonylureas (e.g. tolbutamide, glibenclamide, glimepiride/Amaryl, glipizide), meglitinides (e.g. nateglinide, repaglinide, mitiglinide), alpha-glucosidase inhibitors (e.g. acarbose, miglitol, voglibose), amylin and amylin analogues (e.g. pramlintide, Symlin).

GPR119 (G protein-coupled receptor 119) agonists (e.g. GSK-263A, PSN-821, MBX-2982, APD-597, ZYG-19, DS-8500), GPR40 agonists (e.g. fasiglifam / TAK-875, TUG-424, P-1736, JTT-851, GW9508), GPR120 agonists, GPR142 agonists, systemic or low-absorbable TGR5 (transmembrane G protein-coupled receptor 5)

agonists.

- Other suitable combination partners are: Cycloset (bromocriptine mesylate), inhibitors of 11-beta-HSD (11-beta-hydroxysteroid dehydrogenase; e.g. LY2523199, BMS770767, RG-4929, BMS816336, AZD-8329, HSD-016, BI-135585), activators of glucokinase (e.g. TTP-399, AMG-151, TAK-329, GKM-001), inhibitors of DGAT (diacylglycerol acyltransferase; e.g. LCQ-908), inhibitors of protein tyrosine-phosphatase 1 (e.g. trodusquemine), inhibitors of glucose-6-phosphatase, inhibitors of fructose-1,6-bisphosphatase, inhibitors of glycogen phosphorylase, inhibitors of phosphoenol pyruvate carboxykinase, inhibitors of glycogen synthase kinase, inhibitors of pyruvate dehydrokinase, alpha2-antagonists, CCR-2 (C-C motif receptor 2) antagonists, SGLT-1 inhibitors (e.g. LX-2761), modulators of glucose transporter-4, somatostatin receptor 3 agonists.
- One or more lipid lowering agents are also suitable as combination partners, such as for example: HMG-CoA(3-hydroxy-3-methyl-glutaryl coenzyme A)-reductase inhibitors (e.g. simvastatin, atorvastatin), fibrates (e.g. bezafibrate, fenofibrate), nicotinic acid and the derivatives thereof (e.g. niacin), nicotinic acid receptor 1 agonists, PPAR(peroxisome proliferator-activated receptor)-(alpha, gamma or alpha/gamma) agonists or modulators (e.g. aleglitazar), PPAR-delta agonists, ACAT (acyl-CoA cholesterol acyltransferase) inhibitors (e.g. avasimibe), cholesterol absorption inhibitors (e.g. ezetimibe), bile acid-binding substances (e.g. cholestyramine), ileal bile acid transport (IBAT) inhibitors, MTP (microsomal triglyceride transfer protein) inhibitors, or modulators of PCSK9 (proprotein convertase subtilisin/kexin type 9);

- LDL (low density lipoprotein) receptor up-regulators by liver selective thyroid hormone receptor  $\beta$  agonists, HDL (high density lipoprotein)-raising compounds such as: CETP inhibitors (e.g. torcetrapib, anacetrapid, dalcetrapid, evacetrapid, JTT-302, DRL-17822, TA-8995) or ABC1 regulators; lipid metabolism modulators; PLA2 inhibitors, ApoA-I (apolipoprotein A1) enhancers, thyroid hormone receptor agonists, cholesterol synthesis inhibitors, omega-3 fatty acids and derivatives thereof.

Other suitable combination partners are one or more active substances for the

treatment of obesity, such as for example: sibutramine, tesofensine, orlistat (tetrahydrolipstatin), antagonists of the cannabinoid-1 receptor, MCH-1 (melanin-concentrating hormone 1) receptor antagonists, MC4 (melanocortin 4) receptor agonists and partial agonists, NPY5 (neuropeptide Y 5) or NPY2 antagonists (e.g. velneperit), NPY4 agonists, beta-3-agonists, leptin or leptin mimetics, agonists of the 5HT<sub>2c</sub> receptor (e.g. lorcaserin), or the combinations of bupropione/naltrexone (CONTRAVE), bupropione/zonisamide (EMPATIC), bupropione/phentermine or pramlintide/metreleptin, or phentermine/topiramate (QNEXA).

10 Other suitable combination partners are:

Further gastrointestinal peptides such as Peptide YY 3-36 (PYY3-36) or analogues thereof, pancreatic polypeptide (PP) or analogues thereof, glucagon receptor agonists or antagonists, GIP receptor agonists or antagonists, dual GLP-1/GIP agonists, dual GLP-1/glucagon agonists, ghrelin antagonists or inverse agonists, xenin and analogues thereof.

Other suitable combination partners are:

lipase inhibitors, angiogenesis inhibitors, H3 antagonists, AgRP (Agouti-related protein) inhibitors, triple monoamine uptake inhibitors (norepinephrine and acetylcholine), MetAP2 (methionine aminopeptidase type 2) inhibitors, nasal formulation of the calcium channel blocker diltiazem, antisense molecules against production of fibroblast growth factor receptor 4, prohibitin targeting peptide-1.

Moreover, combinations with drugs for influencing high blood pressure, chronic heart failure or atherosclerosis, such as e.g.: Angiotensin II receptor antagonists (e.g. telmisartan, candesartan, valsartan, losartan, eprosartan, irbesartan, olmesartan, tasosartan, azilsartan), ACE (angiotensin-converting enzyme) inhibitors, ECE (endothelin-converting enzyme) inhibitors, diuretics, beta-blockers, calcium antagonists, centrally acting hypertensives, antagonists of the alpha-2-adrenergic receptor, inhibitors of neutral endopeptidase, thrombocyte aggregation inhibitors and others or combinations thereof are suitable.

In another aspect, this invention relates to the use of a compound according to the invention or a physiologically acceptable salt thereof combined with at least one of

the active substances described above as a combination partner, for preparing a medicament which is suitable for the treatment or prevention of diseases or conditions which can be affected by binding to the receptors for GLP-1 and glucagon and by modulating their activity. This is preferably a disease in the context of the metabolic syndrome, particularly one of the diseases or conditions listed above, most particularly diabetes or obesity or complications thereof.

The use of the compounds according to the invention, or a physiologically acceptable salt thereof, in combination with one or more active substances may take place simultaneously, separately or sequentially.

The use of the compound according to the invention, or a physiologically acceptable salt thereof, in combination with another active substance may take place simultaneously or at staggered times, but particularly within a short space of time. If they are administered simultaneously, the two active substances are given to the patient together; if they are used at staggered times, the two active substances are given to the patient within a period of less than or equal to 12 hours, but particularly less than or equal to 6 hours.

Consequently, in another aspect, this invention relates to a medicament which comprises a compound according to the invention or a physiologically acceptable salt of such a compound and at least one of the active substances described above as combination partners, optionally together with one or more inert carriers and/or diluents.

The compound according to the invention, or physiologically acceptable salt or solvate thereof, and the additional active substance to be combined therewith may both be present together in one formulation, for example a tablet or capsule, or separately in two identical or different formulations, for example as so-called kit-of-parts.

In a further aspect, the invention relates to a method for treating a condition as described herein, the method comprising administering to the patient an effective amount of at least one compound of formula (I) and an effective amount of at least

one other compound useful for treating diabetes, dyslipidemia or high blood pressure. In certain embodiments, the condition is selected from hyperglycemia, type 2 diabetes and obesity, as well as combinations thereof. In particular embodiments, the at least one other compound useful for treating diabetes, dyslipidemia or high blood pressure is selected from the exemplary antidiabetic agents, lipid lowering agents, active substances for the treatment of obesity, gastrointestinal peptides, and drugs for influencing high blood pressure, chronic heart failure or atherosclerosis listed above.

As already indicated before, the effective amount of at least one compound of formula (I) and the additional active ingredient may be administered to the patient simultaneously, or in the alternative, sequentially.

## LEGENDS TO THE FIGURES

**Figure 1.** Body weight development during 4 weeks of subcutaneous treatment with SEQ ID NO: 6 and SEQ ID NO: 7, 50µg/kg bid in female high-fat fed C57BL/6 mice. Data are mean+SEM.

**Figure 2.** Relative body weight change in % during 4 weeks of subcutaneous treatment with SEQ ID NO: 6 and SEQ ID NO: 7, 50µg/kg bid in female high-fat fed C57BL/6 mice. Data are mean+SEM.

**Figure 3.** Determination of total fat mass measured by nuclear magnetic resonance (NMR), two days before and after 4 weeks of treatment with SEQ ID NO: 6 and SEQ ID NO: 7, 50µg/kg bid in female high-fat fed C57BL/6 mice. Data are mean+SEM.

**Figure 4.** Acute effect of s.c. administration of compound SEQ ID NO: 6 and SEQ ID NO: 7 50µg/kg on blood glucose in female high-fat fed C57BL/6 mice. Data are mean+SEM.

**Figure 5a.** Body weight development during 2 weeks of subcutaneous treatment with SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, 50µg/kg bid in female high-fat fed

C57BL/6 mice. Data are mean+SEM.

**Figure 5b.** Body weight development during 2 weeks of subcutaneous treatment with SEQ ID NO: 11 and SEQ ID NO: 15, 50µg/kg bid in female high-fat fed C57BL/6

5 mice. Data are mean+SEM.

**Figure 6a.** Relative body weight change in % during 2 weeks of subcutaneous treatment with SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, 50µg/kg bid in female high-fat fed C57BL/6 mice. Data are mean+SEM.

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**Figure 6b.** Relative body weight change in % during 2 weeks of subcutaneous treatment with SEQ ID NO: 11 and SEQ ID NO: 15, 50µg/kg bid in female high-fat fed C57BL/6 mice. Data are mean+SEM.

15 **Figure 7a.** Acute effect of s.c. administration of compounds SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10 50µg/kg on blood glucose in female high-fat fed C57BL/6 mice. Data are mean+SEM.

20 **Figure 7b.** Acute effect of s.c. administration of compounds SEQ ID NO: 11 and SEQ ID NO: 15 50µg/kg on blood glucose in female high-fat fed C57BL/6 mice. Data are mean+SEM.

25 **Figure 8a.** Daily food consumption during 2 weeks of subcutaneous treatment with SEQ ID NO: 8, SEQ ID NO: 9 and SEQ ID NO: 10, 50µg/kg bid in female high-fat fed C57BL/6 mice.

**Figure 8b.** Daily food consumption during 2 weeks of subcutaneous treatment with SEQ ID NO: 11 and SEQ ID NO: 15, 50µg/kg bid in female high-fat fed C57BL/6 mice.

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## METHODS

**Abbreviations employed are as follows:**

5	AA	amino acid
	AEEAc	(2-(2-aminoethoxy)ethoxy)acetyl
	Aib	alpha-amino-isobutyric acid
	cAMP	cyclic adenosine monophosphate
	Boc	tert-butyloxycarbonyl
10	BOP	(benzotriazol-1-yloxy)tris(dimethylamino)phosphonium hexafluorophosphate
	BSA	bovine serum albumin
	tBu	tertiary butyl
	dAla	D-alanine
15	DCM	dichloromethane
	Dde	1-(4,4-dimethyl-2,6-dioxocyclohexylidene)-ethyl
	ivDde	1-(4,4-dimethyl-2,6-dioxocyclohexylidene)-3-methyl-butyl
	DIC	N,N'-diisopropylcarbodiimide
	DIPEA	N,N-diisopropylethylamine
20	DMEM	Dulbecco's modified Eagle's medium
	DMF	dimethyl formamide
	DMS	dimethylsulfide
	EDT	ethanedithiol
	FA	formic acid
25	FBS	fetal bovine serum
	Fmoc	fluorenylmethyloxycarbonyl
	gGlu	gamma-glutamate ( $\gamma$ E)
	HATU	O-(7-azabenzotriazol-1-yl)-N,N,N',N'-tetramethyluronium hexafluorophosphate
30	HBSS	Hanks' Balanced Salt Solution
	HBTU	2-(1H-benzotriazol-1-yl)-1,1,3,3-tetramethyl-uronium hexafluorophosphate
	HEPES	2-[4-(2-hydroxyethyl)piperazin-1-yl]ethanesulfonic acid
	HOBt	1-hydroxybenzotriazole

	HOSu	N-hydroxysuccinimide
	HPLC	High Performance Liquid Chromatography
	HTRF	Homogenous Time Resolved Fluorescence
	IBMX	3-isobutyl-1-methylxanthine
5	LC/MS	Liquid Chromatography/Mass Spectrometry
	Mmt	monomethoxy-trityl
	Palm	palmitoyl
	PBS	phosphate buffered saline
	PEG	polyethylene glycole
10	PK	pharmacokinetic
	RP-HPLC	reversed-phase high performance liquid chromatography
	Stea	stearyl
	TFA	trifluoroacetic acid
	Trt	trityl
15	UV	ultraviolet

### General synthesis of peptidic compounds

#### **Materials**

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Different Rink-Amide resins (4-(2',4'-Dimethoxyphenyl-Fmoc-aminomethyl)-phenoxyacetamido-norleucylaminomethyl resin, Merck Biosciences; 4-[(2,4-Dimethoxyphenyl)(Fmoc-amino)methyl]phenoxy acetamido methyl resin, Agilent Technologies) were used for the synthesis of peptide amides with loadings in the range of 0.2-0.7 mmol/g.

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Fmoc protected natural amino acids were purchased from Protein Technologies Inc., Senn Chemicals, Merck Biosciences, Novabiochem, Iris Biotech, Bachem, Chem-Impex International or MATRIX Innovation. The following standard amino acids were used throughout the syntheses: Fmoc-L-Ala-OH, Fmoc-Arg(Pbf)-OH, Fmoc-L-Asn(Trt)-OH, Fmoc-L-Asp(OtBu)-OH, Fmoc-L-Cys(Trt)-OH, Fmoc-L-Gln(Trt)-OH, Fmoc-L-Glu(OtBu)-OH, Fmoc-Gly-OH, Fmoc-L-His(Trt)-OH, Fmoc-L-Ile-OH, Fmoc-L-Leu-OH, Fmoc-L-Lys(Boc)-OH, Fmoc-L-Met-OH, Fmoc-L-Phe-OH, Fmoc-L-Pro-OH, Fmoc-L-Ser(tBu)-OH, Fmoc-L-Thr(tBu)-OH, Fmoc-L-Trp(Boc)-OH, Fmoc-L-Tyr(tBu)-

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OH, Fmoc-L-Val-OH.

In addition, the following special amino acids were purchased from the same suppliers as above: Fmoc-L-Lys(ivDde)-OH, Fmoc-L-Lys(Mmt)-OH, Fmoc-Aib-OH,  
5 Fmoc-D-Ser(tBu)-OH, Fmoc-D-Ala-OH, Boc-L-His(Boc)-OH (available as toluene solvate) and Boc-L-His(Trt)-OH.

Furthermore, the building blocks (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-  
10 9-ylmethoxycarbonylamino)hexanoic acid and Boc-L-His(Trt)-Aib-OH were applied. Both building blocks were synthesized separately. A synthesis description is given under EXAMPLES.

The solid phase peptide syntheses were performed for example on a Prelude  
15 Peptide Synthesizer (Protein Technologies Inc) or similar automated synthesizer using standard Fmoc chemistry and HBTU/DIPEA activation. DMF was used as the solvent. Deprotection : 20% piperidine/DMF for 2 x 2.5 min. Washes: 7 x DMF. Coupling 2:5:10 200 mM AA / 500 mM HBTU / 2M DIPEA in DMF 2 x for 20 min. Washes: 5 x DMF.

20 In cases where a Lys-side-chain was modified, Fmoc-L-Lys(ivDde)-OH or Fmoc-L-Lys(Mmt)-OH was used in the corresponding position. After completion of the synthesis, the ivDde group was removed according to a modified literature procedure (S.R. Chhabra et al., Tetrahedron Lett., 1998, 39, 1603), using 4% hydrazine hydrate  
25 in DMF. The Mmt group was removed by repeated treatment with 1% TFA in dichloromethane. The following acylations were carried out by treating the resin with the N-hydroxy succinimide esters of the desired acid or using coupling reagents like HBTU/DIPEA or HOBt/DIC.

30 All the peptides that have been synthesized were cleaved from the resin with King's cleavage cocktail consisting of 82.5% TFA, 5% phenol, 5% water, 5% thioanisole, 2.5% EDT. The crude peptides were then precipitated in diethyl or diisopropyl ether, centrifuged, and lyophilized. Peptides were analyzed by analytical HPLC and checked by ESI mass spectrometry. Crude peptides were purified by a conventional

preparative RP-HPLC purification procedure.

Alternatively, peptides were synthesized by a manual synthesis procedure:

0.3 g Desiccated Rink amide MBHA Resin (0.66 mmol/g) was placed in a  
5 polyethylene vessel equipped with a polypropylene filter. Resin was swollen in DCM  
(15 ml) for 1 h and DMF (15 ml) for 1h. The Fmoc group on the resin was de-  
protected by treating it twice with 20% (v/v) piperidine/DMF solution for 5 and 15 min.  
The resin was washed with DMF/DCM/DMF (6:6:6 time each). A Kaiser test  
(quantitative method) was used for the conformation of removal of Fmoc from solid  
10 support. The C-terminal Fmoc-amino acid (5 equiv. excess corresponding to resin  
loading) in dry DMF was added to the de-protected resin and coupling of the next  
Fmoc-amino acid was initiated with 5 equivalent excess of DIC and HOBt in DMF.  
The concentration of each reactant in the reaction mixture was approximately 0.4 M.  
The mixture was rotated on a rotor at room temperature for 2 h. Resin was filtered  
15 and washed with DMF/DCM/DMF (6:6:6 time each). Kaiser test on peptide resin  
aliquot upon completion of coupling was negative (no colour on the resin). After the  
first amino acid attachment, the unreacted amino group, if any, in the resin was  
capped used acetic anhydride/pyridine/DCM (1:8:8) for 20 minutes to avoid any  
deletion of the sequence. After capping, resin was washed with  
20 DCM/DMF/DCM/DMF (6/6/6/6 time each). The Fmoc group on the C-terminal amino  
acid attached peptidyl resin was deprotected by treating it twice with 20% (v/v)  
piperidine/DMF solution for 5 and 15 min. The resin was washed with  
DMF/DCM/DMF (6:6:6 time each). The Kaiser test on peptide resin aliquot upon  
completion of Fmoc-deprotection was positive.

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The remaining amino acids in target sequence on Rink amide MBHA Resin were  
sequentially coupled using Fmoc AA/DIC/HOBt method using 5 equivalent excess  
corresponding to resin loading in DMF. The concentration of each reactant in the  
reaction mixture was approximately 0.4 M. The mixture was rotated on a rotor at  
30 room temperature for 2 h. Resin was filtered and washed with DMF/DCM/DMF (6:6:6  
time each). After each coupling step and Fmoc deprotection step, a Kaiser test was  
carried out to confirm the completeness of the reaction.

After the completion of the linear sequence, the  $\epsilon$ -amino group of lysine used as

branching point or modification point was deprotected by using 2.5% hydrazine hydrate in DMF for 15 min x 2 and washed with DMF/DCM/DMF (6:6:6 time each). The  $\gamma$ -carboxyl end of glutamic acid was attached to the  $\epsilon$ -amino group of Lys using Fmoc-Glu(OH)-OtBu with DIC/HOBt method (5 equivalent excess with respect to resin loading) in DMF. The mixture was rotated on a rotor at room temperature for 2 h. The resin was filtered and washed with DMF/DCM/DMF (6x30 ml each). The Fmoc group on the glutamic acid was de-protected by treating it twice with 20% (v/v) piperidine/DMF solution for 5 and 15 min (25 ml each). The resin was washed with DMF/ DCM/DMF (6:6:6 time each). A Kaiser test on peptide resin aliquot upon completion of Fmoc-deprotection was positive.

If the side-chain branching also contains one more  $\gamma$ -glutamic acid, a second Fmoc-Glu(OH)-OtBu used for the attachment to the free amino group of  $\gamma$ -glutamic acid with DIC/HOBt method (5 equivalent excess with respect to resin loading) in DMF.

The mixture was rotated on a rotor at room temperature for 2 h. Resin was filtered and washed with DMF/ DCM/DMF (6x30 ml each). The Fmoc group on the  $\gamma$ -glutamic acid was de-protected by treating it twice with 20% (v/v) piperidine/DMF solution for 5 and 15 min (25 mL). The resin was washed with DMF/ DCM/DMF (6:6:6 time each). A Kaiser test on peptide resin aliquot upon completion of Fmoc-deprotection was positive.

Palmitic acid and stearic acid attachment to side chains of glutamic acid:

To the free amino group of  $\gamma$ -glutamic acid, palmitic acid or stearic acid (5 equiv.) dissolved in DMF was added and coupling was initiated by the addition of DIC (5 equiv.) and HOBt (5 equiv.) in DMF. The resin was washed with DMF/DCM/DMF (6:6:6 time each).

Final cleavage of peptide from the resin:

The peptidyl resin synthesized by manual synthesis was washed with DCM (6x10 ml), MeOH (6x10 ml) and ether (6x10 ml) and dried in vacuum desiccators overnight. The cleavage of the peptide from the solid support was achieved by treating the peptide-resin with reagent cocktail (80.0% TFA / 5% thioanisole/5% phenol/ 2.5 % EDT, 2.5 % DMS and 5 % DCM) at room temperature for 3 h. Cleavage mixture was collected by filtration and the resin was washed with TFA (2 ml) and DCM (2 x 5 ml).

The excess TFA and DCM was concentrated to small volume under nitrogen and a small amount of DCM (5-10 ml) was added to the residue and evaporated under nitrogen. The process was repeated 3-4 times to remove most of the volatile impurities. The residue was cooled to 0°C and anhydrous ether was added to precipitate the peptide. The precipitated peptide was centrifuged and the supernatant ether was removed and fresh ether was added to the peptide and re-centrifuged. The crude sample was preparative HPLC purified and lyophilized. The identity of peptide was confirmed by LCMS.

- 10 In addition, a different route for the introduction of the lysine side chain was used, applying a prefunctionalized building block where the side chain is already attached to the lysine (e.g. (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid) as coupling partner in the peptide
- 15 synthesis. 0,67mmol of peptide resin bearing an amino-group were washed with 20ml of dimethylformamide. 2,93g of (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid were dissolved in 20ml of dimethylformamide together with 310mg of hydroxybenzotriazol hydrate and 0,32ml
- 20 of diisopropylcarbodiimide. After stirring of 5 minutes the solution is added to the resin. The resin is agitated for 20h and then washed 3 times with 20ml of dimethylformamide each. A small resin sample is taken and subjected to the Kaiser-test and the Chloranil-test (Kaiser, Colescott, Bossinger, Cook, Anal. Biochem. 1970, 34, 595-598; Chloranil-Test: Vojkovsky, Peptide Research 1995, 8, 236-237). This
- 25 procedure avoids the need of a selective deprotection step as well as the selective attachment of the side chain building blocks on a very advanced synthesis intermediate.

### 30 Analytical HPLC / UPLC

**Method A:** detection at 210 - 225 nm

column: Waters ACQUITY UPLC® CSH™ C18 1.7 µm (150 x 2.1mm) at 50 °C

solvent: H<sub>2</sub>O+0.5%TFA : ACN+0.35%TFA (flow 0.5 ml/min)

gradient: 80:20 (0 min) to 80:20 (3 min) to 25:75 (23 min) to 2:98 (23.5 min) to 2:98 (30.5 min) to 80:20 (31 min) to 80:20 (37 min)

optionally with mass analyser: LCT Premier, electrospray positive ion mode

5 **Method B:** detection at 210 - 225 nm

column: Aries prep XBC 18 (4.6x250 mm x 3.6  $\mu$ m), Temp: 25°C

solvent: H<sub>2</sub>O+0.1%TFA (buffer A) : ACN+0.1%TFA (flow 1 ml/min) (buffer B)

gradient: Equilibration of the column with 2 % buffer B and elution by a gradient of 2% to 70% buffer B during 15 min.

10

**Method C:** detection at 214 nm

column: Waters ACQUITY UPLC® CSH™ C18 1.7  $\mu$ m (150 x 2.1mm) at 50°C

solvent: H<sub>2</sub>O+0.5%TFA : ACN+0.35%TFA (flow 0.5 ml/min)

gradient: 80:20 (0 min) to 80:20 (3 min) to 25:75 (23 min) to 5:95 (23.5 min) to

15

5:95 (25.5 min) to 80:20 (26 min) to 80:20 (30 min)

**General Preparative HPLC Purification Procedure**

The crude peptides were purified either on an Äkta Purifier System, a Jasco semiprep HPLC System or a Agilent 1100 HPLC system. Preparative RP-C18-HPLC columns of different sizes and with different flow rates were used depending on the amount of crude peptide to be purified. Acetonitrile + 0.1% TFA (B) and water + 0.1% TFA (A) were employed as eluents. Product-containing fractions were collected and lyophilized to obtain the purified product, typically as TFA salt.

25

**Solubility and Stability assessment of exendin-4 derivatives**

Prior to the solubility and stability measurement of a peptide batch, its purity was determined through UPLC/MS.

For solubility testing the target concentration was 10mg pure compound/ml.

30

Therefore solutions from solid samples were prepared in two different buffer systems with a concentration of 10mg/mL compound based on the previously determined %purity:

a) Acetate Buffer pH 4.5, 100mM sodium acetate trihydrate, 2.7mg/ml m-cresol

b) Phosphate Buffer pH 7.4, 100mM sodium hydrogen phosphate, 2.7mg/ml m-cresol

UPLC-UV was performed after 2 hours of gentle agitation from the supernatant, which was obtained after 20min of centrifugation at 3000 RCF (relative centrifugal acceleration).

The solubility was determined by the comparison of the UV peak area of 2 $\mu$ L-injection of a buffered sample diluted 1:10 with a standard curve. The standards are dilutions (by injecting various volumes ranging from 0.2 – 2 $\mu$ l) of the DMSO stock solution of the peptide at a concentration of 1.2mg/mL (based on %purity). The sample also served as starting point (t0) for the stability testing.

For chemical and physical stability testing, an aliquot of the supernatant obtained for solubility was stored for 7 days at 40°C. After the time course the sample was centrifuged for 20 min at 3000 RCF. Then 2 $\mu$ l of the 1:10 diluted supernatant were analyzed with UPLC-UV.

The chemical stability was rated through the relative loss of purity calculated by the equation:

$$[(\text{purity at starting point}) - (\text{purity after 7 days})] / (\text{purity at starting point}) * 100\%$$

The purity is calculated as

$$[(\text{peak area peptide}) / (\text{total peak area})] * 100\%$$

In addition the remaining amount of peptide was determined by comparing the peak areas of the target peptide after 7 days to the peak area at starting point. This results in the parameter "%remaining peptide", following the equation:

$$\% \text{remaining peptide} = [(\text{peak area peptide } t7) / (\text{peak area peptide } t0)] * 100\%.$$

### Dynamic Light Scattering (DLS)

Dynamic Light Scattering (DLS) measures light scattered from particles based on Brownian motion, the interaction of particles with solvent molecules. A focused laser light beam is used to illuminate the liquid sample and the time dependent, scattered light intensity fluctuations are recorded and correlated. The first order result from a DLS experiment is an intensity distribution of particle sizes. The intensity distribution

is naturally weighted according to the scattering intensity of each particle fraction or family. For biological materials or polymers the particle scattering intensity is proportional to the square of the molecular weight. The mean hydrodynamic diameter of the particles present in the sample is directly related to the rate of change of scattered light intensity and is calculated using the Stokes-Einstein relationship. The polydispersity index is a measure of the broadness of the size distribution and is calculated by standard methods described in ISO13321:1996 and ISO22412:2008.

Method A: DLS measurements were performed on a W130i apparatus (Avid Nano Ltd, High Wycombe, UK) and using a low-volume disposable cuvette (UVette, Eppendorf AG, Hamburg, Germany). The data were processed with i-Size 3.0 provided by Avid Nano. Hydrodynamic radii were determined with non-negatively constrained least squares (NNLS) methods using DynaLS algorithms. Measurements were taken at an angle of 90°.

Method B: DLS measurements were performed on a Nanosizer ZS (Malvern Instruments, Malvern, UK) and using disposable UV cuvettes (Brand macro , 2,5 mL and Brand semi-micro 1,5 mL, Brand GmbH + Co KG, Wertheim, Germany). The data were processed with Malvern Zetasizer software Version 7.10 or 7.01. Hydrodynamic radii were determined with non-negatively constrained least squares (NNLS) methods. Measurements were taken in NIBS (Non-Invasive Back-Scatter) mode at an angle of 173°.

Method C: DLS measurements were performed on a DynaPro Plate Reader II (Wyatt Technology, Santa Barbara, CA, US) and using a low volume, non-treated, black polystyrene 384 assay plate with clear bottom (Corning, NY, US). The data were processed with Dynamics V 7.1.9.3 provided by Wyatt Technology. Hydrodynamic radii were determined with non-negatively constrained least squares (NNLS) methods using Dynals algorithms. Measurements were taken with an 830 nm laser light source at an angle of 158°.

#### **In vitro cellular assays for GLP-1, glucagon and GIP receptor efficacy**

Agonism of compounds for the receptors was determined by functional assays

measuring cAMP response of HEK-293 cell lines stably expressing human GLP-1, GIP or glucagon receptor.

cAMP content of cells was determined using a kit from Cisbio Corp. (cat. no.

- 5 62AM4PEJ) based on HTRF (Homogenous Time Resolved Fluorescence). For preparation, cells were split into T175 culture flasks and grown overnight to near confluency in medium (DMEM / 10% FBS). Medium was then removed and cells washed with PBS lacking calcium and magnesium, followed by proteinase treatment with accutase (Sigma-Aldrich cat. no. A6964). Detached cells were washed and
- 10 resuspended in assay buffer (1 x HBSS; 20 mM HEPES, 0.1% BSA, 2 mM IBMX) and cellular density determined. They were then diluted to 400000 cells/ml and 25  $\mu$ l aliquots dispensed into the wells of 96-well plates. For measurement, 25  $\mu$ l of test compound in assay buffer was added to the wells, followed by incubation for 30 minutes at room temperature. After addition of HTRF reagents diluted in lysis buffer
- 15 (kit components), the plates were incubated for 1 hr, followed by measurement of the fluorescence ratio at 665 / 616 nm. In vitro potency of agonists was quantified by determining the concentrations that caused 50% activation of maximal response (EC50).

20

#### **Bioanalytical screening method for quantification of exendin-4 derivatives in mice and pigs**

Mice were dosed 1 mg/kg subcutaneously (s.c.). The mice were sacrificed and blood samples were collected after 0.25, 0.5, 1, 2, 4, 8, 16 and 24 hours post application.

- 25 Plasma samples were analyzed after protein precipitation via liquid chromatography mass spectrometry (LC/MS). PK parameters and half-life were calculated using WinonLin Version 5.2.1 (non-compartment model).

- Female Göttinger minipigs were dosed 0.05 mg/kg, 0.075 mg/kg or 0.1 mg/kg
- 30 subcutaneously (s.c.). Blood samples were collected after 0.25, 0.5, 1, 2, 4, 8, 24, 32, 48, 56 and 72 hours post application. Plasma samples were analyzed after protein precipitation via liquid chromatography mass spectrometry (LC/MS). PK parameters and half-life were calculated using WinonLin Version 5.2.1 (non-compartment model).



**Gastric emptying and intestinal passage in mice**

Female NMRI-mice of a body weight between 20 and 30 g are used. Mice are adapted to housing conditions for at least one week.

- 5 Mice are overnight fasted, while water remains available all the time. On the study day, mice are weighed, single-caged and allowed access to 500 mg of feed for 30 min, while water is removed. At the end of the 30 min feeding period, remaining feed is removed and weighed. 60 min later, a coloured, non-caloric bolus is instilled via gavage into the stomach. The test compound / reference compound or its vehicle
- 10 in the control group is administered subcutaneously, to reach C<sub>max</sub> when coloured bolus is administered. After another 30 min, the animals are sacrificed and the stomach and the small intestine prepared. The filled stomach is weighed, emptied, carefully cleaned and dried and reweighed. The calculated stomach content indicates the degree of gastric emptying. The small intestine is straightened without force and
- 15 measured in length. Then the distance from the gastric beginning of the gut to the tip of the farthest travelled intestinal content bolus is measured. The intestinal passage is given as relation in percent of the latter distance and the total length of the small intestine.

Comparable data can be obtained for both female and male mice.

- 20 Statistical analyses are performed with Everstat 6.0 by 1-way-ANOVA, followed by Dunnetts or Newman-Keuls as post-hoc test, respectively. Differences are considered statistically significant at the  $p < 0.05$  level. As post hoc test Dunnet's Test is applied to compare versus vehicle control, only. Newman-Keul's Test is applied for
- 25 all pairwise comparisons (i.e. versus vehicle and reference groups).

**Automated assessment of feed intake in mice**

- Female NMRI-mice of a body weight between 20 and 30 g are used. Mice are adapted to housing conditions for at least one week and for at least one day single-
- 30 caged in the assessment equipment, when basal data are recorded simultaneously. On the study day, test product is administered subcutaneously close to the lights-off phase (12 h lights off) and assessment of feed consumption is directly started afterwards. Assessment included continued monitoring (every 30 min) over 22 hours. Repetition of this procedure over several days is possible. Restriction of assessment

to 22 hours is for practical reasons to allow for reweighing of animals, refilling of feed and water and drug administration between procedures. Results can be assessed as cumulated data over 22 hours or differentiated to 30 min intervals.

Comparable data can be obtained for both female and male mice.

5

Statistical analyses are performed with Everstat 6.0 by two-way ANOVA on repeated measures and Dunnett's post-hoc analyses. Differences are considered statistically significant at the  $p < 0.05$  level.

10 **Acute and chronic effects after subcutaneous treatment on blood glucose and body weight in female diet-induced obese (DIO) C57BL/6 mice**

C57BL/6 Harlan mice are housed in groups in a specific pathogen-free barrier facility on a 12h light/dark cycle with free access to water and standard or high-fat diet. After 16 weeks of prefeeding on high-fat diet, mice are stratified to treatment groups ( $n =$

15 8), so that each group has similar mean body weight. An age-matched group with *ad-libitum* access to standard chow is included as standard control group. Prior to the start of treatment, mice are subcutaneously (s.c.) injected with vehicle solution and weighed for 3 days to acclimate them to the procedures.

20 1) Acute effect on blood glucose in fed female DIO mice: initial blood samples are taken just before first administration (s.c.) of vehicle (phosphate buffer solution) or the exendin-4 derivatives (dissolved in phosphate buffer), respectively. The volume of administration is 5 mL/kg. The animals have access to water and their corresponding diet during the experiment. Blood glucose levels are measured at  $t = 0$  h,  $t = 1$  h,  $t = 2$   
25 h,  $t = 3$  h,  $t = 4$  h,  $t = 6$  h and  $t = 24$  h (method: Accu-Check glucometer). Blood sampling is performed by tail incision without anaesthesia.

2) Chronic effect on body weight in female DIO mice: mice are treated twice daily s.c. in the morning and in the evening, respectively, at the beginning and the end of the  
30 light phase with either vehicle or exendin-4 derivatives for 4 weeks. Body weight is recorded daily. Two days before start of treatment and on day 26, total fat mass is measured by nuclear magnetic resonance (NMR).

Statistical analyses are performed with Everstat 6.0 by repeated measures two-way

ANOVA and Dunnetts post-hoc analyses (glucose profile) and 1-way-ANOVA, followed by Dunnetts post-hoc test (body weight, body fat). Differences versus vehicle-treated DIO control mice are considered statistically significant at the  $p < 0.05$  level.

5

**Effects of 4 weeks of treatment on glucose, HbA1c and oral glucose tolerance in female diabetic dbdb-mice**

10 Female diabetic dbdb-mice of mean non-fasted glucose value of 10-30 mmol/l and a body weight of 35-50 g are used. Mice are individually marked and are adapted to housing conditions for at least one week.

7 days prior to study start, baseline values for non-fasted glucose and HbA1c are determined, 5 days prior to study start, mice are assigned to groups and cages (5  
15 mice per cage, 10 per group) according to their HbA1c values to ensure even distribution of lower and higher values between groups (stratification).

Mice are treated for 4 weeks, by twice daily subcutaneous administration in the morning and the afternoon. Blood samples from the tail tip are obtained for HbA1c on  
20 study day 21 and oral glucose tolerance is assessed in the 4th week.

An oral glucose tolerance test is done in the morning without prior extra compound administration to majorly assess the effect of chronic treatment and less of acute compound administration. Mice are fasted for 4 hours prior to oral glucose  
25 administration (2 g/kg,  $t = 0$  min). Blood samples are drawn prior to glucose administration and at 15, 30, 60, 90, 120, and 180 min. Feed is returned after the last blood sampling. Results are represented as change from baseline, glucose in mmol/l and HbA1c in %.

30 Statistical analyses are performed with Everstat Version 6.0 based on SAS by 1-way-ANOVA, followed by Dunnett's post-hoc test against vehicle-control. Differences are considered statistically significant at the  $p < 0.05$  level.

**Glucose lowering in non-fasted female diabetic dbdb-mice**

Female diabetic dbdb-mice of mean non-fasted glucose value of 20-30 mmol/l and a body weight of 35-50 g are used. Mice are individually marked and are adapted to housing conditions for at least one week.

3-5 days prior to study start mice are assigned to groups and cages (4 mice per cage, 8 per group) according to their non-fasted glucose values to ensure even distribution of lower and higher values between groups (stratification). On the study day, mice are weighed and dosed ( $t = 0$ ). Immediately prior to compound administration feed is removed while water remains available, and a first blood sample at a tail incision is drawn (baseline). Further blood samples are drawn at the tail incision at 30, 60, 90, 120, 240, 360, and 480 min.

Statistical analyses are performed with Everstat Version 6.0 based on SAS by 2-way-ANOVA on repeated measures, followed by Dunnett's post-hoc test against vehicle-control. Differences are considered statistically significant at the  $p < 0.05$  level.

**EXAMPLES**

The invention is further illustrated by the following examples.

Example 1:

Synthesis of SEQ ID NO: 6

The solid phase synthesis as described in Methods was carried out on Novabiochem Rink-Amide resin (4-(2',4'-Dimethoxyphenyl-Fmoc-aminomethyl)-phenoxyacetamidonorleucylaminomethyl resin), 100-200 mesh, loading of 0.23 mmol/g. The Fmoc-synthesis strategy was applied with HBTU/DIPEA-activation. In position 14 Fmoc-Lys(ivDde)-OH and in position 1 Boc-His(Trt)-OH were used in the solid phase synthesis protocol. The ivDde-group was cleaved from the peptide on resin according to literature (S.R. Chhabra et al., Tetrahedron Lett. 1998, 39, 1603-1606). Hereafter Palm-gGlu-gGlu-OSu was coupled to the liberated amino-group employing DIPEA as base. The peptide was cleaved from the resin with King's cocktail (D. S. King, C. G. Fields, G. B. Fields, Int. J. Peptide Protein Res. 1990, 36, 255-266). The crude

product was purified via preparative HPLC on a Waters column (XBridge, BEH130, Prep C18 5µM) using an acetonitrile/water gradient (both buffers with 0,1% TFA). The purified peptide was analysed by LCMS (Method A).

Deconvolution of the mass signals found under the peak with retention time 11.30 min revealed the peptide mass 4782.6 which is in line with the expected value of 4782.6.

#### Example 2:

##### Synthesis of SEQ ID NO: 7

10 The solid phase synthesis as described in Methods was carried out on Novabiochem Rink-Amide resin (4-(2',4'-Dimethoxyphenyl-Fmoc-aminomethyl)-phenoxyacetamido-norleucylaminomethyl resin), 100-200 mesh, loading of 0.23 mmol/g. The Fmoc-synthesis strategy was applied with HBTU/DIPEA-activation. In position 14 Fmoc-Lys(ivDde)-OH and in position 1 Boc-His(Trt)-OH were used in the solid phase

15 synthesis protocol. The ivDde-group was cleaved from the peptide on resin according to literature (S.R. Chhabra et al., Tetrahedron Lett. 1998, 39, 1603-1606). Hereafter Palm-gGlu-gGlu-OSu was coupled to the liberated amino-group employing DIPEA as base. The peptide was cleaved from the resin with King's cocktail (D. S. King, C. G. Fields, G. B. Fields, Int. J. Peptide Protein Res. 1990, 36, 255-266). The crude

20 product was purified via preparative HPLC on a Waters column (XBridge, BEH130, Prep C18 5µM) using an acetonitrile/water gradient (both buffers with 0,1% TFA). The purified peptide was analysed by LCMS (Method A).

Deconvolution of the mass signals found under the peak with retention time 10.77 min revealed the peptide mass 4768.6 which is in line with the expected value of

25 4768.6.

In an analogous way, the peptides listed in Table 3 were synthesized and characterized.

Table 3: list of synthesized peptides and comparison of calculated vs. found molecular weight

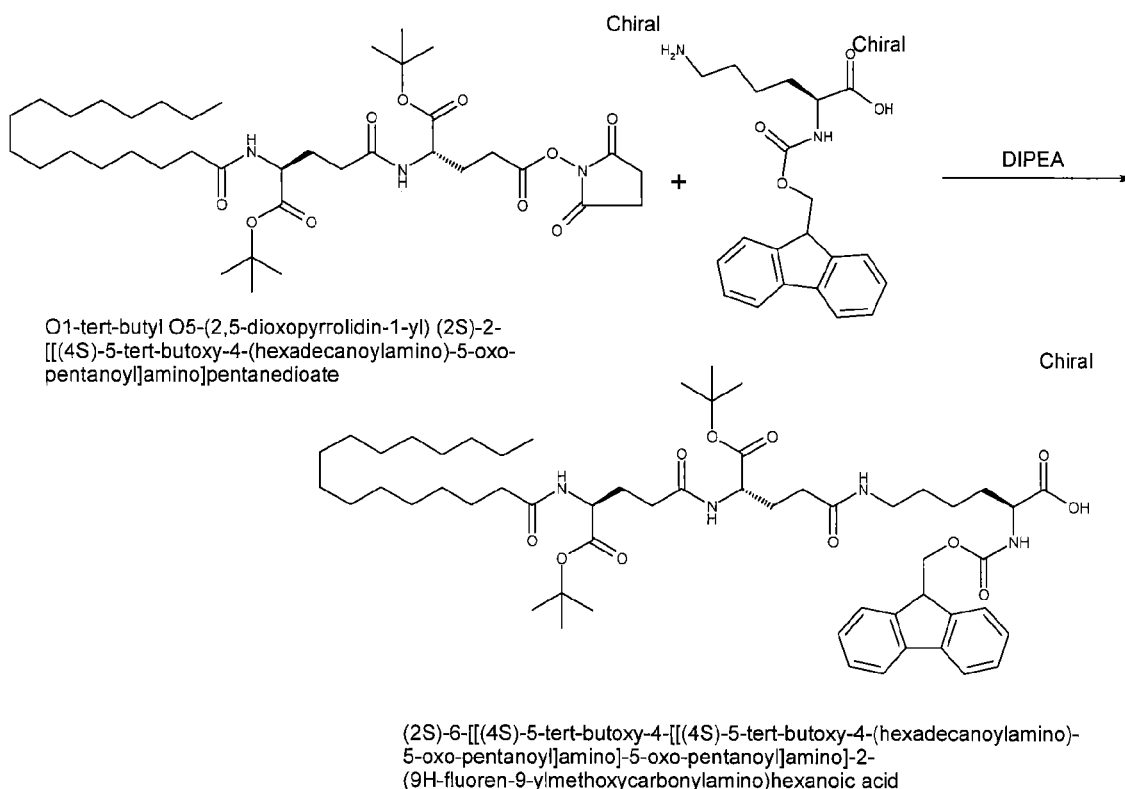
SEQ ID NO	calc. Mass	found mass	Monoisotopic or average mass
6	4782,6	4782.6	monoisotopic
7	4768,6	4768.6	monoisotopic
8	4825,7	4825.6	monoisotopic
9	4667,6	4667.6	monoisotopic
10	4724,6	4724.6	monoisotopic
11	4639,6	4639.6	monoisotopic
12	4929,7	4929.7	monoisotopic
13	4957,7	4957.7	monoisotopic
14	4973,8	4973.8	monoisotopic
15	4784,6	4784.7	monoisotopic
16	4839,7	4839.8	monoisotopic
17	4798,6	4798.6	monoisotopic
18	4675,5	4675.4	monoisotopic
19	4689,5	4689.5	monoisotopic
20	4577.3	4575.6	average

5

Examples 3a and 3b: Alternative synthesis of SEQ ID NO: 6 and SEQ ID NO. 7.

Example 3 a: Synthesis of building block (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid

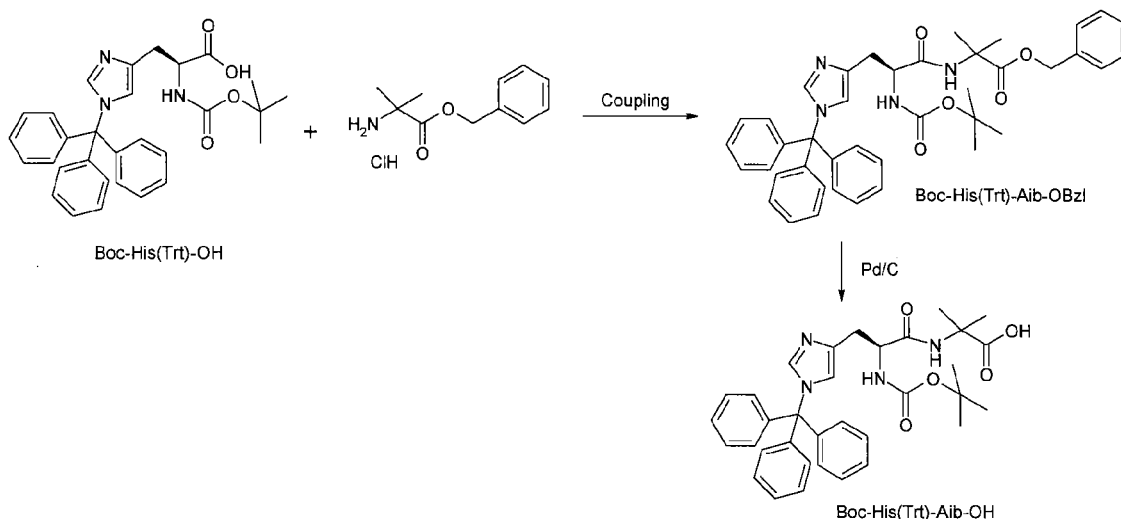
10



- 20g of O1-tert-butyl O5-(2,5-dioxopyrrolidin-1-yl) (2S)-2-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]pentanedioate, which was obtained from WuXi AppTec, were suspended in 200ml of ethyl acetate. In parallel 12g of Fmoc-Lys-OH were suspended in 100ml of ethyl acetate and 13ml of ethyldiisopropyl amine were added. Both parts were combined followed by the addition of further ethyl acetate (50ml) and stirred at room temperature. After 3h of stirring an extra of 5ml ethyldiisopropyl amine were added. The suspension was stirred for 20h. The suspension was filtered and extracted 2 times with 200ml of 10% citric acid solution each followed by one extraction with 200ml of brine. The organic layer was dried with sodium sulfate. Sodium sulfate was filtered off and the solution evaporated to dryness.
- The remaining solid was taken up with 560ml of methanol and 140ml of water was added slowly. After 4h of stirring the precipitate was filtered off and washed once with 100ml of methanol/water (4:1). The product was dried under vacuum yielding in 21g of (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid. Calculated MW = 976.5 g/mol, MW found

$[M+H]^+ = 977.5$  g/mol.

### Synthesis of building block Boc-L-His(Trt)-Aib-OH



5

2.5g of Boc-L-His(Trt)-OH were suspended in 25ml of ethylacetate and 1.55g of H-Aib-OBzl x HCl and 2,3g of HBTU were added followed by 2,6ml of N-ethylmorpholin. Suspension was stirred for 4.5h. Mixture was then extracted three times with 20ml of a 8% sodium bicarbonate solution followed by one wash with water. Phases were separated and the organic layer dried over sodium sulfate. After removal of the drying agent the solution was evaporated to dryness and 4.5g of a yellow oil were obtained consisting of Boc-L-His(Trt)-Aib-OBzl with a purity of >90%.

10

4.3g of Boc-L-His(Trt)-Aib-OBzl were dissolved in 30ml THF and 3ml of ethylacetate. 0.43g of the hydrogenation catalyst Pd/C (5%) were added and the compound is hydrogenated at 30°C for 2h at atmospheric hydrogen pressure using a balloon. The catalyst is filtered off and washed with 30ml of ethylacetate. The solution was stirred for several hours until precipitation occurs. Precipitate is filtered off and dried under vacuum to obtain 2.45g of Boc-L-His(Trt)-Aib-OH.

15

20

These building blocks can be used to synthesize SEQ ID NO: 6, SEQ ID No: 7 or other corresponding peptides as described in the Methods.

*Synthesis of SEQ ID NO: 6 with building block (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-*

25



*2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid and with building block Boc-L-His(Trt)-Aib-OH*

The solid phase synthesis as described in methods was carried out on Agilent Rink-  
5 Amide resin 4-[(2,4-Dimethoxyphenyl) (Fmoc-amino)methyl]phenoxy acetamido  
methyl resin with a loading of 0,27mmol/g. The Fmoc-synthesis strategy was applied  
with HBTU/DIPEA activation. In position 14 (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-  
butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-  
(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid was coupled in a threefold  
10 excess with HBTU/DIPEA activation and the coupling time controlled until the  
ninhydrin-test showed a negative result (Kaiser, Colescott, Bossinger, Cook,  
Analytical Biochemistry 34, 1970, 595ff). For position 1 and 2 the building block Boc-  
L-His(Trt)-Aib-OH was applied in a threefold excess also with HBTU/DIPEA activation  
and the coupling time controlled until the ninhydrin-test showed a negative result. The  
15 peptide was cleaved from the resin with King's cocktail (King, Fields, Fields, Int. J.  
Peptide Protein Res. 36, 1990, 255-266). The crude product was obtained  
(calculated average MW = 4785,6 g/mol; average MW found = 4785,7 g/mol). The  
crude peptide is purified as described under Methods.

20 Example 3b: Synthesis of SEQ ID NO: 7 with building block (2S)-6-[[[(4S)-5-tert-  
butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-  
pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid and with  
building block Boc-L-His(Trt)-Aib-OH

25 The solid phase synthesis as described in methods was carried out on Agilent Rink-  
Amide resin 4-[(2,4-Dimethoxyphenyl) (Fmoc-amino)methyl]phenoxy acetamido  
methyl resin with a loading of 0,27mmol/g. The Fmoc-synthesis strategy was applied  
with HBTU/DIPEA activation. In position 14 (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-  
butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-  
30 (9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid was coupled in a threefold  
excess with HBTU/DIPEA activation and the coupling time controlled until the  
ninhydrin-test showed a negative result (Kaiser, Colescott, Bossinger, Cook,  
Analytical Biochemistry 1970, 34, 595-598). For position 1 and 2 the building block  
Boc-L-His(Trt)-Aib-OH was applied in a threefold excess also with HBTU/DIPEA

activation and the coupling time controlled until the ninhydrin-test showed a negative result. The peptide was cleaved from the resin with King's cocktail (King, Fields, Fields, Int. J. Peptide Protein Res. 1990, 36, 255-266). The crude product was obtained (calculated average MW = 4771,6 g/mol; average MW found = 4771.3 g/mol). The crude peptide is purified as described under Methods.

#### Example 4: Stability and solubility

Solubility and stability of peptidic compounds were assessed as described in Methods. The results are given in Table 4.

Table 4: Stability and solubility

SEQ ID NO	Chemical stability [relative purity loss 7 days 40°C] (%)		solubility [mg/ml]	
	pH4.5	pH7.4	pH4.5	pH7.4
6	<b>3.1</b>	<b>n.d.</b>	<b>&gt;7</b>	<b>n.d.</b>
7	<b>4.6</b>	<b>3.8</b>	<b>&gt;7</b>	<b>&gt;7</b>
8	<b>4.4</b>	<b>2.8</b>	<b>&gt;7</b>	<b>&gt;7</b>

#### Example 5: In vitro data on GLP-1, glucagon and GIP receptor

Potencies of peptidic compounds at the GLP-1, glucagon and GIP receptors were determined by exposing cells expressing human glucagon receptor (hGlucagon R), human GIP receptor (hGIP-R) or human GLP-1 receptor (hGLP-1 R) to the listed compounds at increasing concentrations and measuring the formed cAMP as described in Methods.

The results are shown in Table 5:

Table 5. EC<sub>50</sub> values of exendin-4 derivatives at GLP-1, Glucagon and GIP receptors (indicated in pM)

SEQ ID NO	EC <sub>50</sub> hGLP-1R	EC <sub>50</sub> hGlucagon-R	EC <sub>50</sub> hGIP-R
6	3.2	66.2	4170.0
7	2.1	24.0	1964.3
8	3.0	57.2	2310.0
9	4.2	22.2	1080.0
10	4.7	29.1	1100.0
11	6.9	58.9	2210.0
12	3.3	53.2	2880.0
13	6.4	22.3	1810.0
14	10.2	19.4	2870.0
15	5.5	33.5	3580.0
16	6.0	208.0	6740.0
17	9.0	149.0	8540.0
18	1.2	3.2	193.0
19	1.8	5.9	148.0
20	6.8	5.8	86.1

5

#### Example 6: Comparison Testing

A selection of inventive exendin-4 derivatives carrying an Aib amino acid in positions 27 and 34, Pro at position 32 and Lys at position 35 and 39 has been tested versus corresponding compounds having in these positions the amino acid residues of native exendin-4 (Lys27, Ser32, Gly34, Ala35, Ser39) and otherwise identical amino acid sequence. The reference pair compounds and the corresponding EC<sub>50</sub> values at GLP-1, Glucagon and GIP receptors (indicated in pM) are given in Table 6. As shown, the inventive exendin-4 derivatives show a reduced activity on the GIP receptor compared to the corresponding derivatives carrying the amino acids as in native exendin-4, keeping their GLP-1R activity.

Table 6. Comparison of exendin-4 derivatives carrying an Aib amino acid in positions 27 and 34, Pro at position 32 and Lys at position 35 and 39 vs. exendin-4 derivatives comprising at these positions the amino acid residues of native exendin-4 (Lys27, Ser32, Gly34, Ala35, Ser39) and otherwise identical amino acid sequence. EC50 values at GLP-1, Glucagon and GIP receptors are indicated in pM.

SEQ ID NO	EC50 hGLP-1R	EC50 hGlucagon-R	EC50 hGIP-1	residue differences
18	1.2	3.2	193.0	Aib27, Pro32, Aib34, Lys35, Lys39
7	2.1	24.0	1964.3	Lys27, Ser32, Gly34, Ala35, Ser39
19	1.8	5.9	148.0	Aib27, Pro32, Aib34, Lys35, Lys39
6	3.2	66.2	4170.0	Lys27, Ser32, Gly34, Ala35, Ser39
20	6.8	5.8	86.1	Aib27, Pro32, Aib34, Lys35, Lys39
9	4.2	22.2	1080.0	Lys27, Ser32, Gly34, Ala35, Ser39

Example 7: Acute and chronic effects of SEQ ID NO: 6 and of SEQ ID NO: 7 after subcutaneous treatment on blood glucose and body weight in female diet-induced obese (DIO) C57BL/6 mice

#### 1) Glucose profile

After blood sampling to determine the blood glucose baseline level, fed diet-induced obese female C57BL/6 mice were administered 50 µg/kg of SEQ ID NO: 6, 50 µg/kg of SEQ ID NO: 7 or phosphate buffered solution (vehicle control on standard or high-fat diet) subcutaneously. At predefined time points, more blood samples were taken

to measure blood glucose and generate the blood glucose profile over 24 h. SEQ ID NO: 6 and SEQ ID NO: 7 demonstrated a significant decrease in blood glucose compared to DIO control mice for time points t=1, 2, 3, 4, 6 and 24 h post compound dosing ( $p < 0.0001$ , 1-W-ANOVA-RM, post hoc Dunnett's Test; Fig. 4, mean  $\pm$  SEM).

## 2) Body weight

Female obese C57BL/6 mice were treated for 4 weeks twice daily subcutaneously with 50  $\mu$ g/kg SEQ ID NO: 6, 50  $\mu$ g/kg SEQ ID NO: 7 or vehicle. Body weight was recorded daily, and body fat content was determined before the start and after 4 weeks of treatment.

Treatment with 50  $\mu$ g/kg SEQ ID NO: 6 showed a statistically significant decrease when compared to vehicle DIO control mice in daily body weight beginning on day 7 and continuing through the end of the study ( $p < 0.0001$  by the end of the study).

Treatment with 50  $\mu$ g/kg SEQ ID NO: 7 reduced body weight significantly when compared to vehicle DIO control mice beginning on day 5 and continuing through the end of the study ( $p < 0.0001$  by the end of the study, Table 7, Fig. 1 and 2). These changes resulted from a decrease in body fat, as shown by the absolute changes in body fat content (Table 7, Fig. 3).

Table 7. Weight change in DIO mice over a 4-week treatment period (mean  $\pm$  SEM)

Example (Dose)	Overall weight change (g)	Body fat change (g)
Control standard diet	+ 2.17 $\pm$ 1.93	+ 0.25 $\pm$ 0.34
Control high-fat diet	+ 7.44 $\pm$ 1.07	+ 2.39 $\pm$ 0.43
SEQ ID NO: 6 (50 $\mu$ g/kg bid)	- 11.71 $\pm$ 1.45	- 4.44 $\pm$ 0.47
SEQ ID NO: 7 (50 $\mu$ g/kg bid)	- 8.45 $\pm$ 3.2	- 3.83 $\pm$ 1.38

Example 8: Acute and chronic effects of SEQ ID NO: 8, SEQ ID NO: 9, SEQ ID NO: 10, SEQ ID NO: 11 and SEQ ID NO: 15 after subcutaneous treatment on blood glucose and body weight in female diet-induced obese (DIO) C57BL/6 mice

5     1) Glucose profile

After blood sampling to determine the blood glucose baseline level, fed diet-induced obese female C57BL/6 mice were administered 50 µg/kg of SEQ ID NO: 8, 50 µg/kg of SEQ ID NO: 9, 50 µg/kg of SEQ ID NO: 10 (Fig. 7a), 50 µg/kg of SEQ ID NO: 11, 50 µg/kg of SEQ ID NO: 15 (Fig. 7b) or phosphate buffered solution (vehicle control  
10     on standard or high-fat diet) subcutaneously. At predefined time points, more blood samples were taken to measure blood glucose and generate the blood glucose profile over 24 h.

All compounds demonstrated a significant decrease in blood glucose compared to  
15     DIO control mice for time points t=1, 2, 3, 4, 6 and 24 h post compound dosing (t=0h, p < 0.0001, 1-W-ANOVA-RM, post hoc Dunnett's Test; Fig. 7a and b, mean ± SEM).

2) Body weight and food consumption

Female obese C57BL/6 mice were treated for 2 weeks twice daily subcutaneously  
20     with 50 µg/kg SEQ ID NO: 8, 50 µg/kg SEQ ID NO: 9 and 50 µg/kg of SEQ ID NO: 10 or vehicle (Fig. 5a and 6a) and 50 µg/kg of SEQ ID NO: 11 and 50 µg/kg of SEQ ID NO: 15 or vehicle (Fig. 5b and 6b), respectively.

Body weight and food consumption were recorded daily.

25

All compounds showed a statistically significant decrease when compared to vehicle DIO control mice in daily body weight beginning on day 6 and continuing through the end of the study (p<0.0001 by the end of the study, Table 8, Figs. 5a and b and 6a and b). These changes resulted from an initial decrease in food consumption and  
30     were maintained although food consumption recovered during prolonged study period (Fig. 8a and 8b).

Table 8. Weight change in DIO mice over a 2-week treatment period (mean  $\pm$  SEM)

Example (Dose)	Overall weight change (g)
Control standard diet	+ 1.0 $\pm$ 0.3
Control high-fat diet	+ 4.3 $\pm$ 0.6
SEQ ID NO: 8 (50 $\mu$ g/kg bid)	- 1.66 $\pm$ 0.5
SEQ ID NO: 9 (50 $\mu$ g/kg bid)	- 2.5 $\pm$ 0.2
SEQ ID NO: 10 (50 $\mu$ g/kg bid)	- 2.3 $\pm$ 0.6
SEQ ID NO: 11 (50 $\mu$ g/kg bid)	- 2.1 $\pm$ 0.6
SEQ ID NO: 15 (50 $\mu$ g/kg bid)	- 2.6 $\pm$ 0.5

## 5 Table 9. Sequences

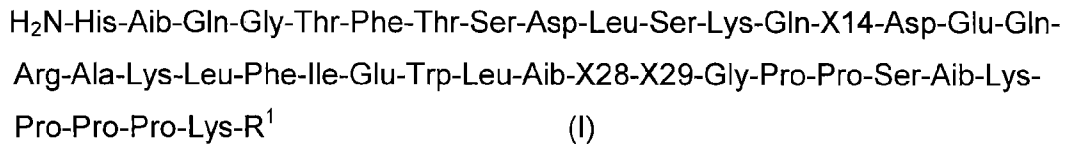
SEQ. ID	sequence
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2	H-A-E-G-T-F-T-S-D-V-S-S-Y-L-E-G-Q-A-A-K(gGlu-Palm)-E-F-I-A-W-L-V-R-G-R-G-OH
3	H-S-Q-G-T-F-T-S-D-Y-S-K-Y-L-D-S-R-R-A-Q-D-F-V-Q-W-L-M-N-T-OH
4	H-G-E-G-T-F-T-S-D-L-S-K-Q-M-E-E-E-A-V-R-L-F-I-E-W-L-K-N-G-G-P-S-S-G-A-P-P-P-S-NH <sub>2</sub>
5	Y-A-E-G-T-F-I-S-D-Y-S-I-A-M-D-K-I-H-Q-Q-D-F-V-N-W-L-L-A-Q-K-G-K-K-N-D-W-K-H-N-I-T-Q-OH
6	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-dAla-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
7	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
8	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-K-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
9	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-Stea]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
10	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-Stea]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-K-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
11	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>

12	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K(AEEAc-AEEAc-gGlu-Palm)-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
13	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K(AEEAc-AEEAc-gGlu-Stea)-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
14	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K(AEEAc-AEEAc-AEEAc-Stea)-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-A-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
15	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-S-G-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
16	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-K-dAla-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
17	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-Aib-S-dAla-G-P-P-S-Aib-K-P-P-P-K-NH <sub>2</sub>
18	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-K-A-G-G-P-S-S-G-A-P-P-S-NH <sub>2</sub>
19	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-gGlu-Palm]-D-E-Q-R-A-K-L-F-I-E-W-L-K-A-dAla-G-P-S-S-G-A-P-P-S-NH <sub>2</sub> -
20	H-Aib-Q-G-T-F-T-S-D-L-S-K-Q-K[gGlu-Stea]-D-E-Q-R-A-K-L-F-I-E-W-L-K-A-G-G-P-S-S-G-A-P-P-S-NH <sub>2</sub> -



## Claims

- 5      1. A peptidic compound having the formula (I):



(I)

wherein

X14 represents an amino acid residue with a functionalized -NH<sub>2</sub> side chain group, selected from the group consisting of Lys, Orn, Dab, or Dap, wherein the -NH<sub>2</sub> side chain group is functionalized by -Z-C(O)-R<sup>5</sup>, wherein

Z represents a linker in all stereoisomeric forms and

R<sup>5</sup> is a moiety comprising up to 50 carbon atoms and heteroatoms selected from N and O,

X28 represents an amino acid residue selected from Ala, Lys and Ser,

X29 represents an amino acid residue selected from D-Ala and Gly,

$R^1$  is  $NH_2$  or  $OH$ ,

or a salt or solvate thereof.

- 25      2. A compound of claim 1,  
             wherein R<sup>1</sup> is NH<sub>2</sub>,  
             or a salt or solvate thereof.
- 30      3. A compound according to any one of claims 1 to 2,  
             wherein the peptidic compound has a relative activity of at least 0.09%  
             compared to that of natural glucagon at the glucagon receptor.
4. A compound according to any one of claims 1 to 3,  
             wherein the peptidic compound exhibits a relative activity of at least 0.1%

3. A compound according to any one of claims 1 to 2,  
wherein the peptidic compound has a relative activity of at least 0.09% compared to that of natural glucagon at the glucagon receptor.

4. A compound according to any one of claims 1 to 3,  
wherein the peptidic compound exhibits a relative activity of at least 0.1%

compared to that of GLP-1(7-36)-amide at the GLP-1 receptor.

5. A compound of any one of claims 1 to 4, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized with a group -Z-C(O)R<sup>5</sup>, wherein

Z represents a group selected from gGlu, gGlu-gGlu, AEEAc-AEEAc-gGlu and AEEAc-AEEAc-AEEAc and

R<sup>5</sup> represents a group selected from pentadecanyl or heptadecanyl.

6. A compound of any one of claims 1 to 5, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-hexadecanoylamino-butyryl-, (S)-4-Carboxy-4-octadecanoylamino-butyryl-, (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-, (2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-hexadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-, (2-{2-[2-(2-{2-[(4S)-4-Carboxy-4-octadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-, [2-(2-{2-[2-(2-{2-[2-(2-Octadecanoylamino-ethoxy)-ethoxy]-acetylamino}-ethoxy)-ethoxy]-acetylamino}-ethoxy)-ethoxy]-acetyl-,

X28 represents Ala,

X29 represents an amino acid residue selected from D-Ala and Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

7. A compound of any one of claims 1 to 6, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents Ser,

X29 represents an amino acid residue selected from D-Ala and Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

8. A compound of any one of claims 1 to 7, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-, (S)-4-Carboxy-4-octadecanoylamino-butyryl-,

X28 represents Lys,

5 X29 represents an amino acid residue selected from D-Ala and Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

9. A compound of any one of claims 1 to 8, wherein

10 X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents an amino acid residue selected from Ala, Lys and Ser,

X29 represents D-Ala,

R<sup>1</sup> represents NH<sub>2</sub>,

15 or a salt or solvate thereof.

10. A compound of any one of claims 1 to 9, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-hexadecanoylamino-butyryl-, (S)-4-Carboxy-4-

20 octadecanoylamino-butyryl-, (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-, (2-{2-[2-(2-{[(4S)-4-Carboxy-4-hexadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-, (2-{2-[2-(2-{[(4S)-4-Carboxy-4-octadecanoylamino-butyrylamino]-ethoxy}-ethoxy)-acetylamino]-ethoxy}-ethoxy)-acetyl-, [2-(2-{2-[2-(2-{2-[2-(2-Octadecanoylamino-ethoxy)-ethoxy]-acetylamino}-ethoxy)-ethoxy]-acetylamino}-ethoxy)-ethoxy]-acetyl-,

X28 represents an amino acid residue selected from Ala, Lys and Ser,

X29 represents Gly,

R<sup>1</sup> represents NH<sub>2</sub>,

30 or a salt or solvate thereof.

11. A compound of any one of claims 1 to 10, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents Ala,

X29 represents an amino acid residue selected from Gly and D-Ala,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

5

12. A compound of any one of claims 1 to 11, wherein

X14 represents Lys wherein the -NH<sub>2</sub> side chain group is functionalized by (S)-4-Carboxy-4-((S)-4-carboxy-4-hexadecanoylamino-butyrylamino)-butyryl-,

X28 represents an amino acid residue selected from Ala, Ser and Lys,

10 X29 represents an amino acid residue selected from Gly and D-Ala,

R<sup>1</sup> represents NH<sub>2</sub>,

or a salt or solvate thereof.

13. The compound of any one of claims 1 to 12, selected from the compounds of

15 SEQ ID NO: 6-17, as well as salts or solvates thereof.

14. The compound of claim 1, wherein the compound is represented by SEQ ID NO.: 6, or a salt or solvate thereof.

20 15. The compound of claim 1, wherein the compound is represented by SEQ ID NO.: 7, or a salt or solvate thereof.

16. The compound of claim 1, wherein the compound is represented by SEQ ID NO.: 8, or a salt or solvate thereof.

25

17. The compound of claim 1, wherein the compound is represented by SEQ ID NO.: 9, or a salt or solvate thereof.

18. The compound of claim 1, wherein the compound is represented by SEQ ID NO.: 10, or a salt or solvate thereof.

30

19. The compound of claim 1, wherein the compound is represented by SEQ ID NO.: 11, or a salt or solvate thereof.

20. The compound of claim 1, wherein the compound is represented by SEQ ID NO.:  
15, or a salt or solvate thereof.

21. The compound of any one of claims 1 to 20 for use in medicine, particularly in  
5 human medicine.

22. The compound of any one of claims 1 to 20 for use as pharmaceutical.

23. The compound for use according to any one of claims 21 to 22 which is present  
10 as an active agent in a pharmaceutical composition together with at least one  
pharmaceutically acceptable carrier.

24. The compound for use according to any one of claims 21 to 23 together with at  
least one additional therapeutically active agent.

15

25. The compound for use according to claim 24, wherein the at least one additional  
therapeutically active agent is selected from the group consisting of:

insulin and insulin derivatives;

GLP-1, GLP-1 analogues and GLP-1 receptor agonists;

20 DPP-4 inhibitors;

SGLT2 inhibitors;

dual SGLT2/SGLT1 inhibitors;

biguanides, thiazolidinediones, dual PPAR agonists, sulfonylureas, meglitinides,  
alpha-glucosidase inhibitors, amylin and amylin analogues;

25 GPR119 agonists, GPR40 agonists, GPR120 agonists, GPR142 agonists,  
systemic or low-absorbable TGR5 agonists;

bromocriptine mesylate, inhibitors of 11-beta-HSD, activators of glucokinase,

inhibitors of DGAT, inhibitors of protein tyrosine-phosphatase 1, inhibitors of

glucose-6-phosphatase, inhibitors of fructose-1,6-bisphosphatase, inhibitors of

30 glycogen phosphorylase, inhibitors of phosphoenol pyruvate carboxykinase,

inhibitors of glycogen synthase kinase, inhibitors of pyruvate dehydrokinase,

alpha2-antagonists, CCR-2 antagonists, SGLT-1 inhibitors, modulators of

glucose transporter-4, somatostatin receptor 3 agonists;

lipid lowering agents;

active substances for the treatment of obesity;

gastrointestinal peptides;

lipase inhibitors, angiogenesis inhibitors, H3 antagonists, AgRP inhibitors, triple  
monoamine uptake inhibitors, MetAP2 inhibitors, nasal formulation of the calcium  
channel blocker diltiazem, antisense molecules against production of fibroblast  
growth factor receptor 4, prohibitin targeting peptide-1; and  
drugs for influencing high blood pressure, chronic heart failure or atherosclerosis.

26. The compound for use according to any one of claims 21 to 25 for the treatment  
of glucose intolerance, insulin resistance, pre-diabetes, increased fasting  
glucose, hyperglycemia, type 2 diabetes, hypertension, dyslipidemia,  
arteriosclerosis, coronary heart disease, peripheral artery disease, stroke or any  
combination of these individual disease components.

27. The compound for use according to any one of claims 21 to 25 for control of  
appetite, feeding and calory intake, increase of energy expenditure, prevention of  
weight gain, promotion of weight loss, reduction of excess body weight and  
altogether treatment of obesity, including morbid obesity.

28. The compound for use according to any one of claims 21 to 25 for the treatment  
or prevention of hepatosteatosi.

29. The compound for use according to any one of claims 21 to 25 for the treatment  
or prevention of hyperglycemia, type 2 diabetes, obesity.

30. The compound for use according to any one of claims 21 to 25 for the  
simultaneous treatment of diabetes and obesity.

31. The compound for use according to any one of claims 21 to 25 for the treatment  
of diabetes.

32. The compound for use according to any one of claims 21 to 25 for reducing the  
intestinal passage, increasing the gastric content and/or reducing the food intake  
of a patient.

33. The compound for use according to any one of claims 21 to 25 for reducing blood glucose levels and/or reducing HbA1c levels of a patient.
- 5 34. The compound for use according to any one of claims 21 to 25 for reducing body weight of a patient.
35. A pharmaceutical composition comprising at least one compound according to any one of claims 1 to 20 or a physiological acceptable salt or solvate of any of  
10 them, for use as a pharmaceutical.
36. A pharmaceutical composition comprising at least one compound according to any one of claims 1 to 20 or a physiologically acceptable salt or solvate of any of  
15 them.
37. A pharmaceutical composition comprising at least one compound according to any one of claims 1 to 20 or a physiologically acceptable salt or solvate of any of them and at least one additional pharmaceutically active ingredient.
- 20 38. A method for treating hyperglycemia, type 2 diabetes or obesity in a patient, the method comprising administering to the patient an effective amount of at least one compound of formula (I) as claimed in any one of claims 1 to 20 and an effective amount of at least one other compound useful for treating diabetes, obesity, dyslipidemia or high blood pressure.
- 25 39. The method according to claim 38, wherein the effective amount of at least one compound of formula (I) and the additional active ingredient are administered to the patient simultaneously.
- 30 40. The method as claimed in claim 38, wherein the effective amount of at least one compound of formula (I) and the additional active ingredient are administered to the patient sequentially.
41. The compound as claimed in claims 1 to 20 synthesized via solid phase

synthesis where building block (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid is used.

- 5 42. Building block (2S)-6-[[[(4S)-5-tert-butoxy-4-[[[(4S)-5-tert-butoxy-4-(hexadecanoylamino)-5-oxo-pentanoyl]amino]-5-oxo-pentanoyl]amino]-2-(9H-fluoren-9-ylmethoxycarbonylamino)hexanoic acid.



Fig. 1

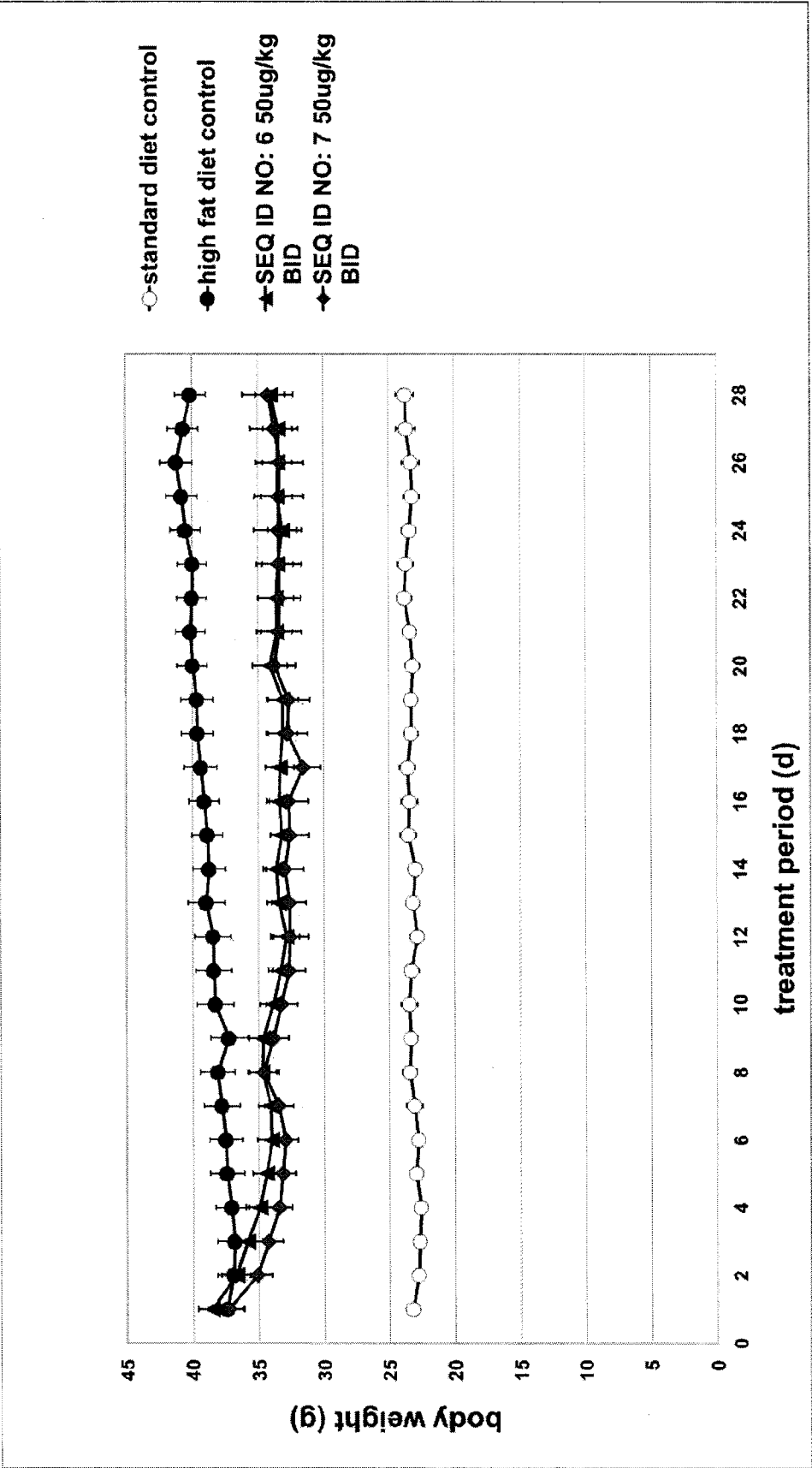


Fig. 2

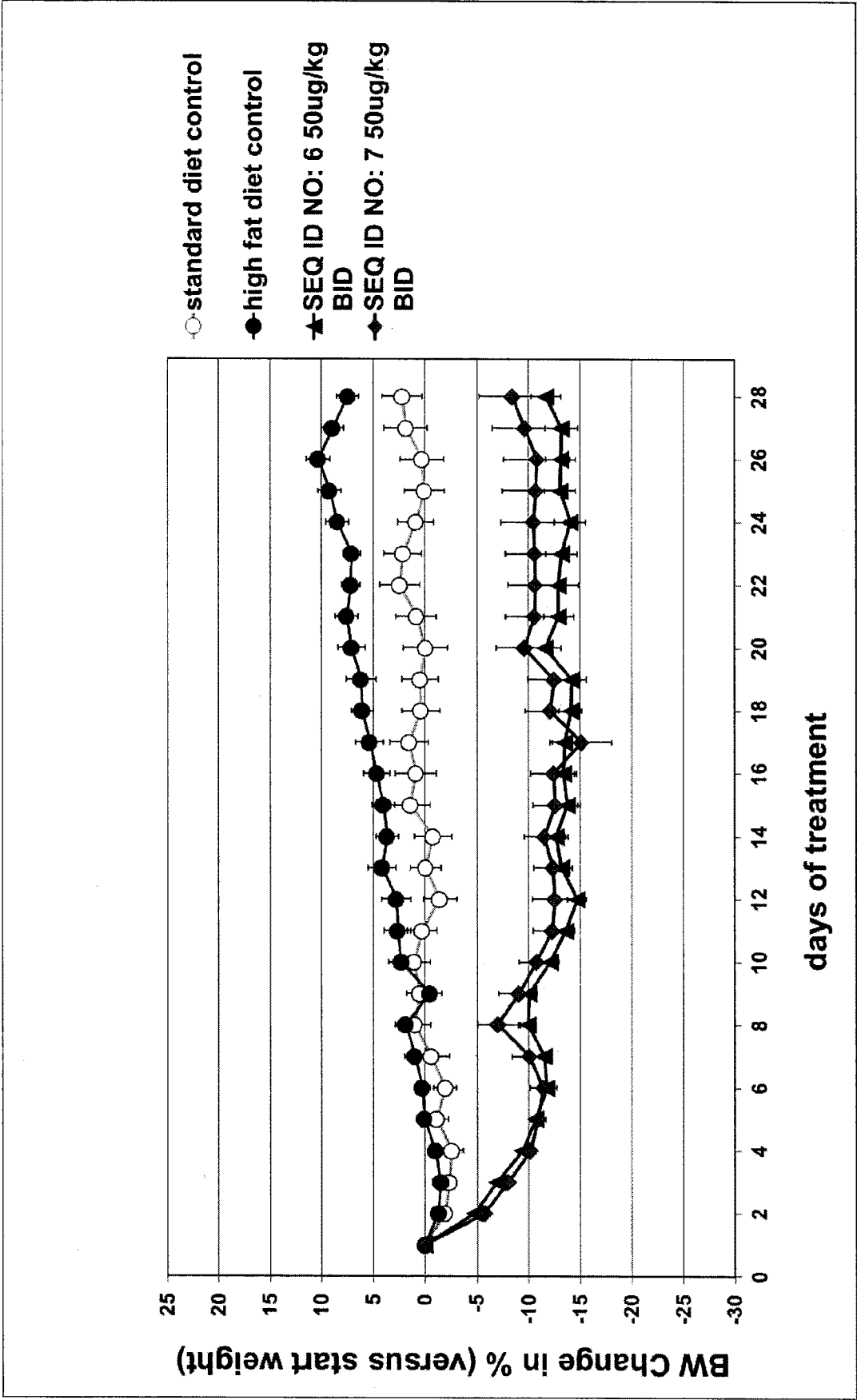


Fig. 3

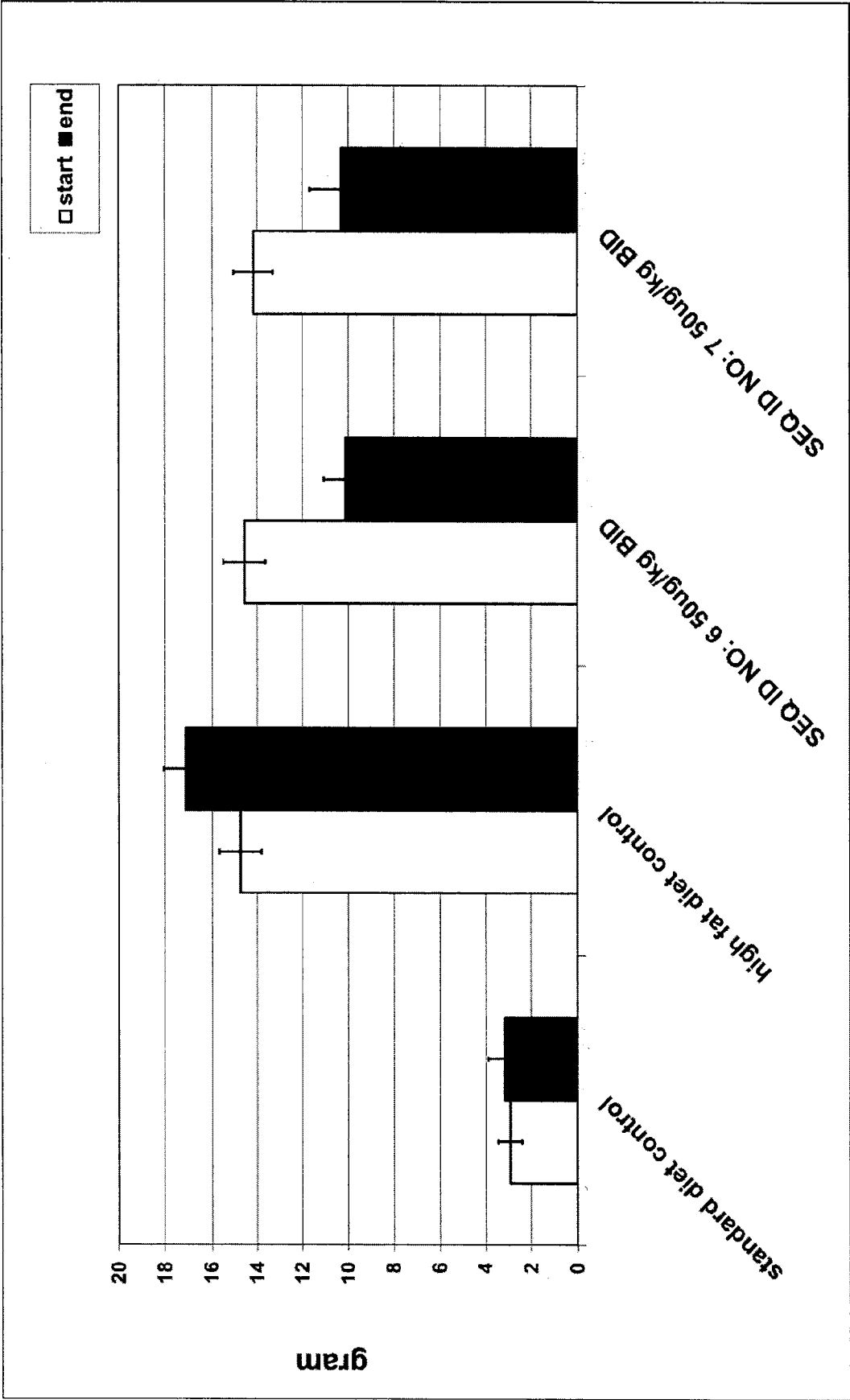


Fig. 4

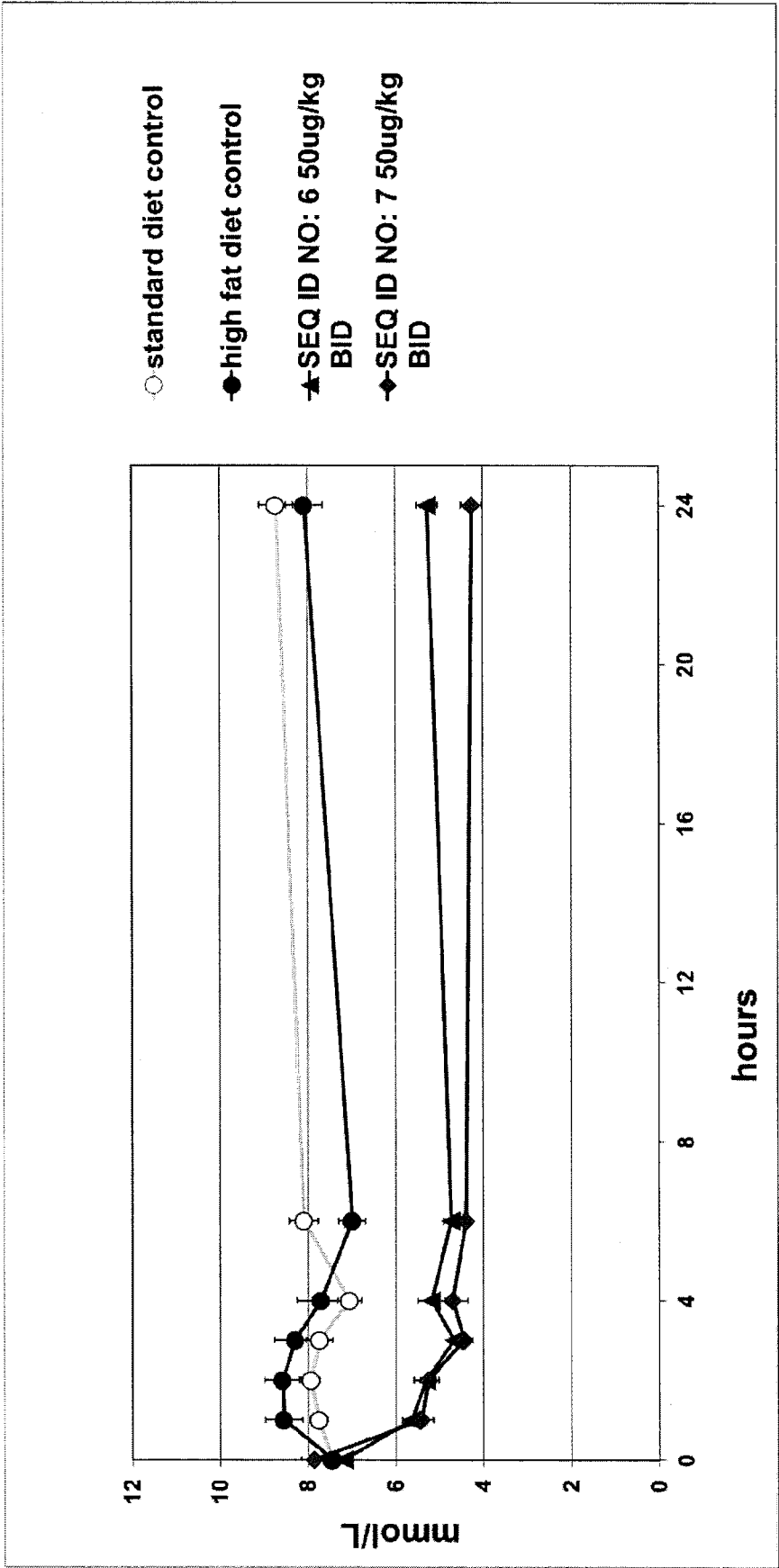


Fig. 5 a)

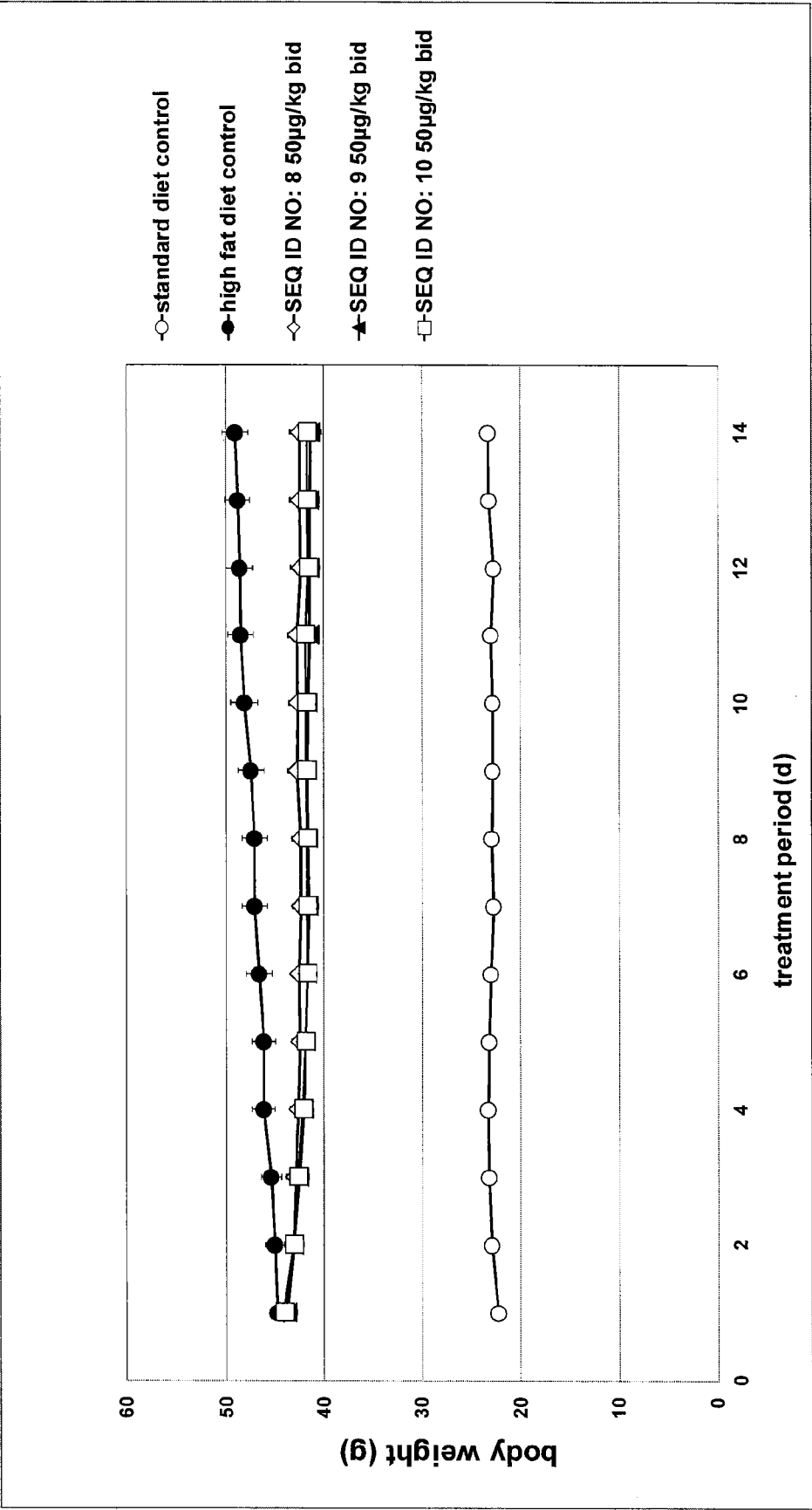


Fig. 5 b)

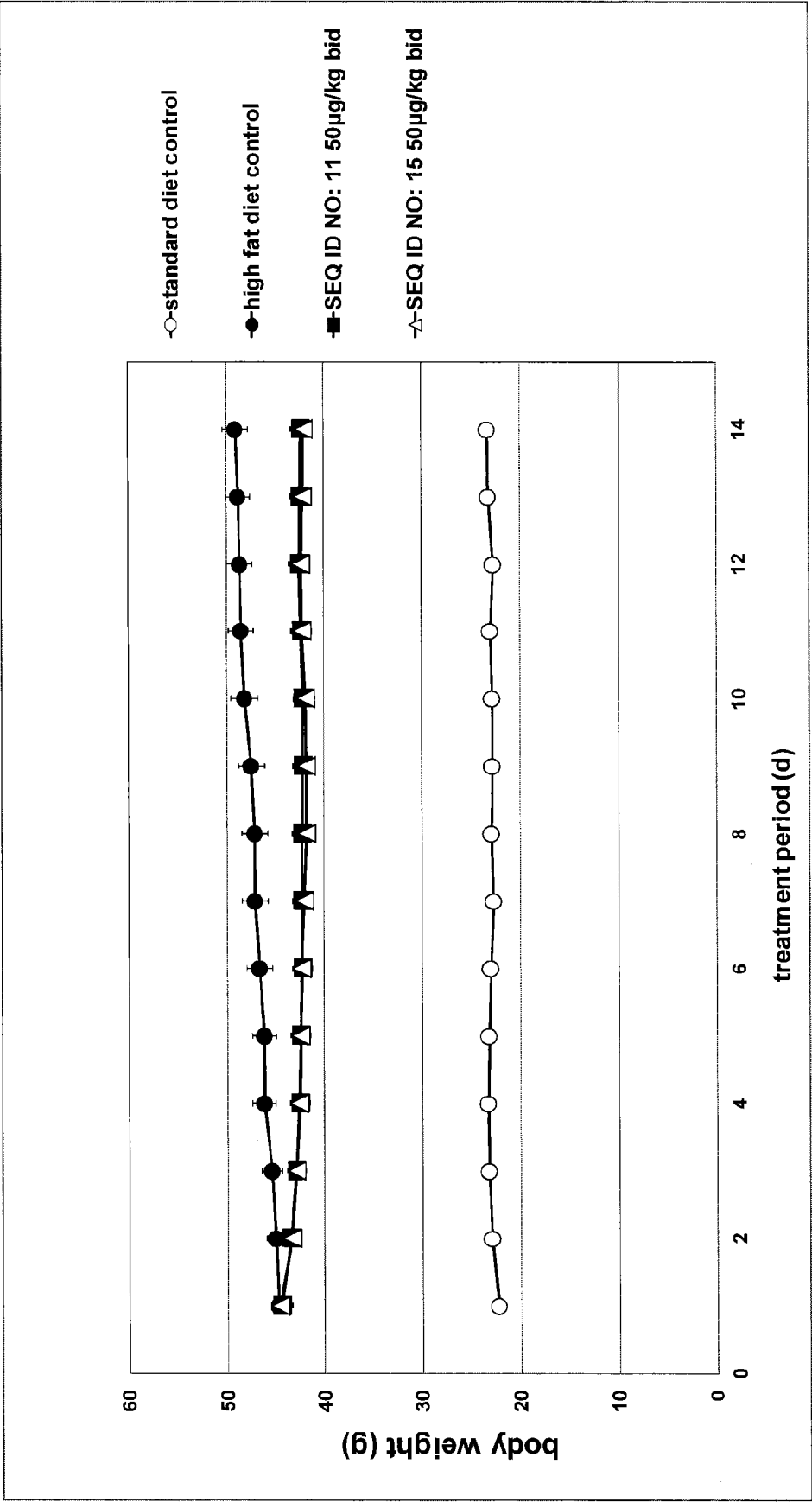


Fig. 6 a)

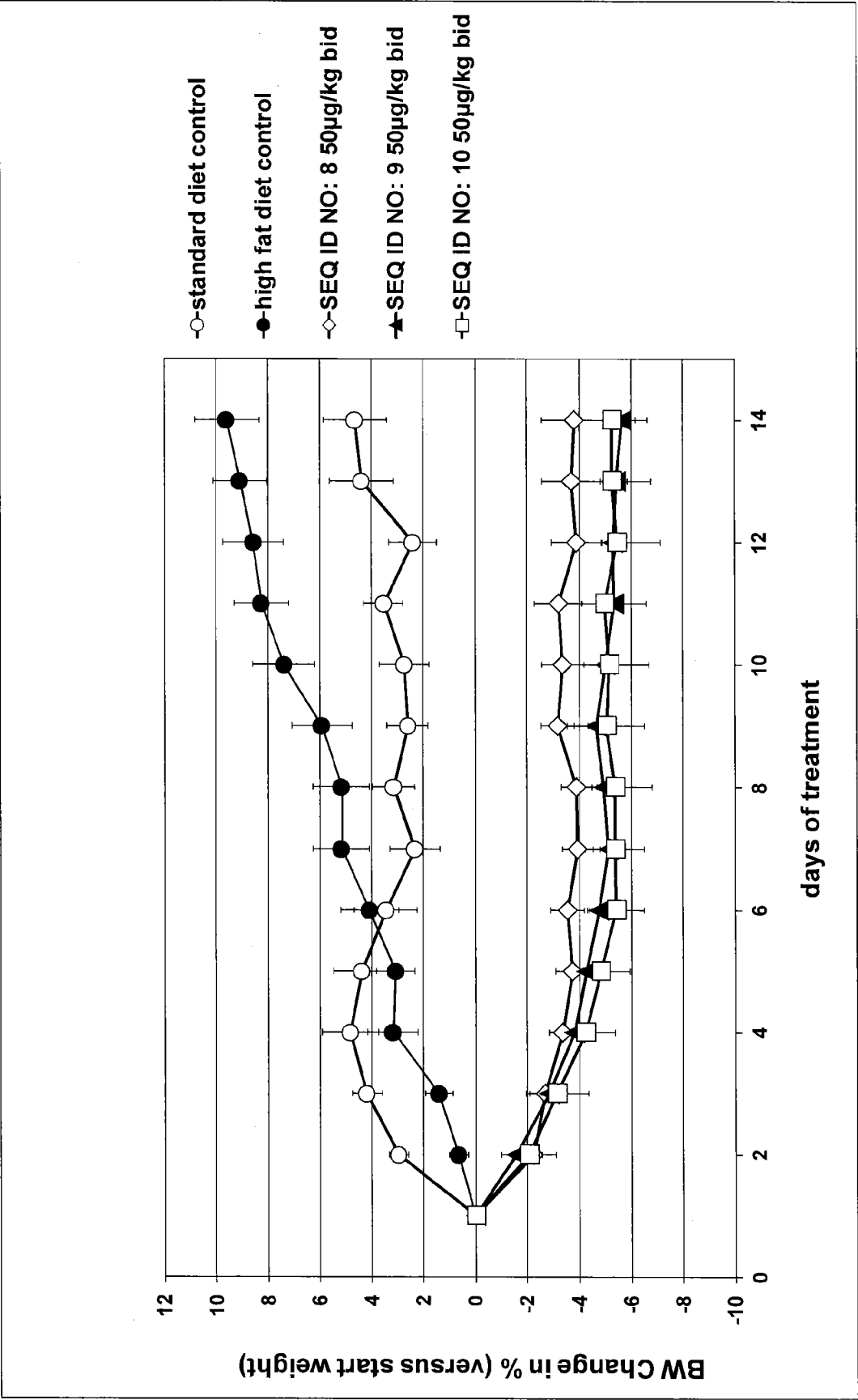


Fig. 6 b)

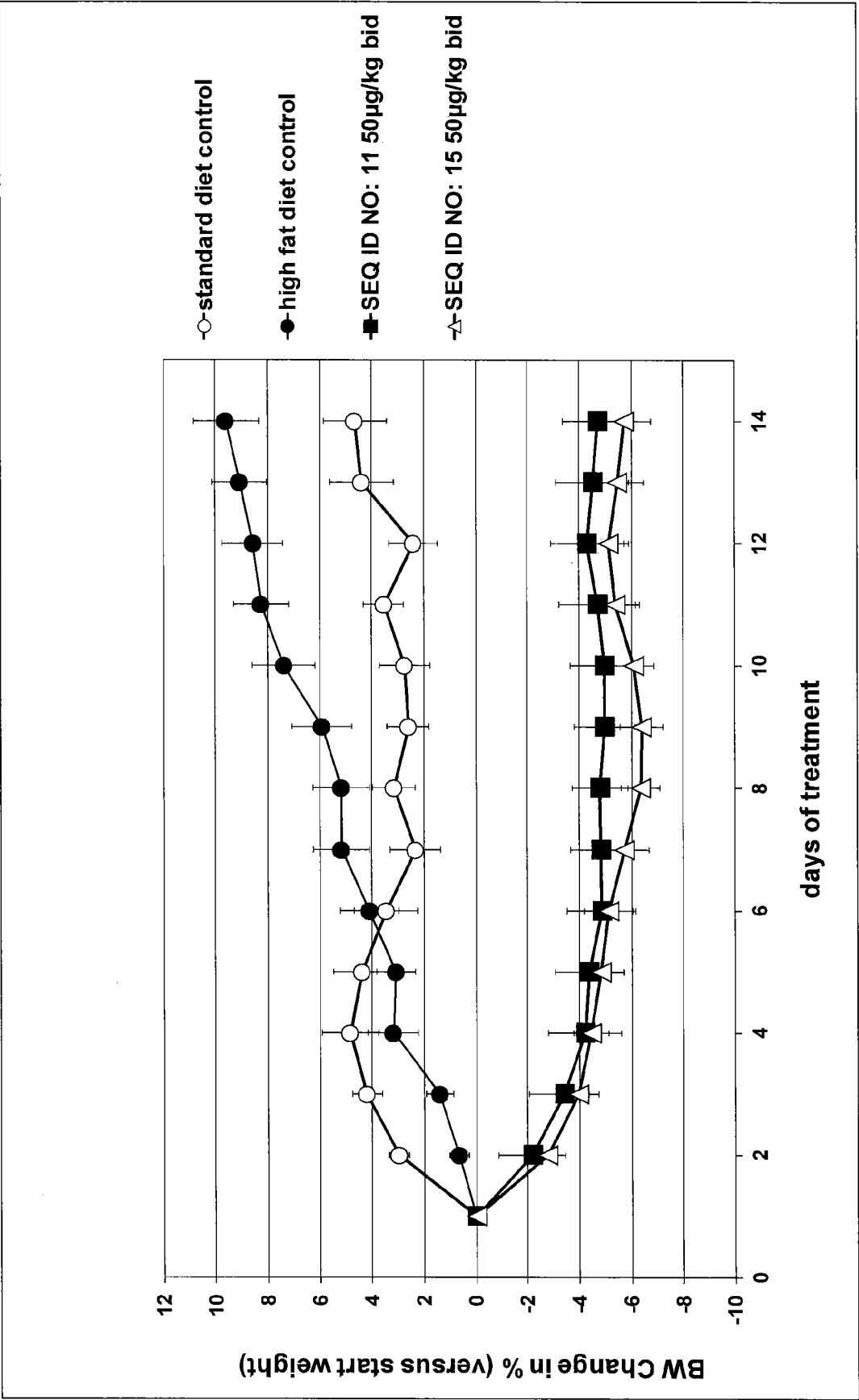




Fig. 7 a)

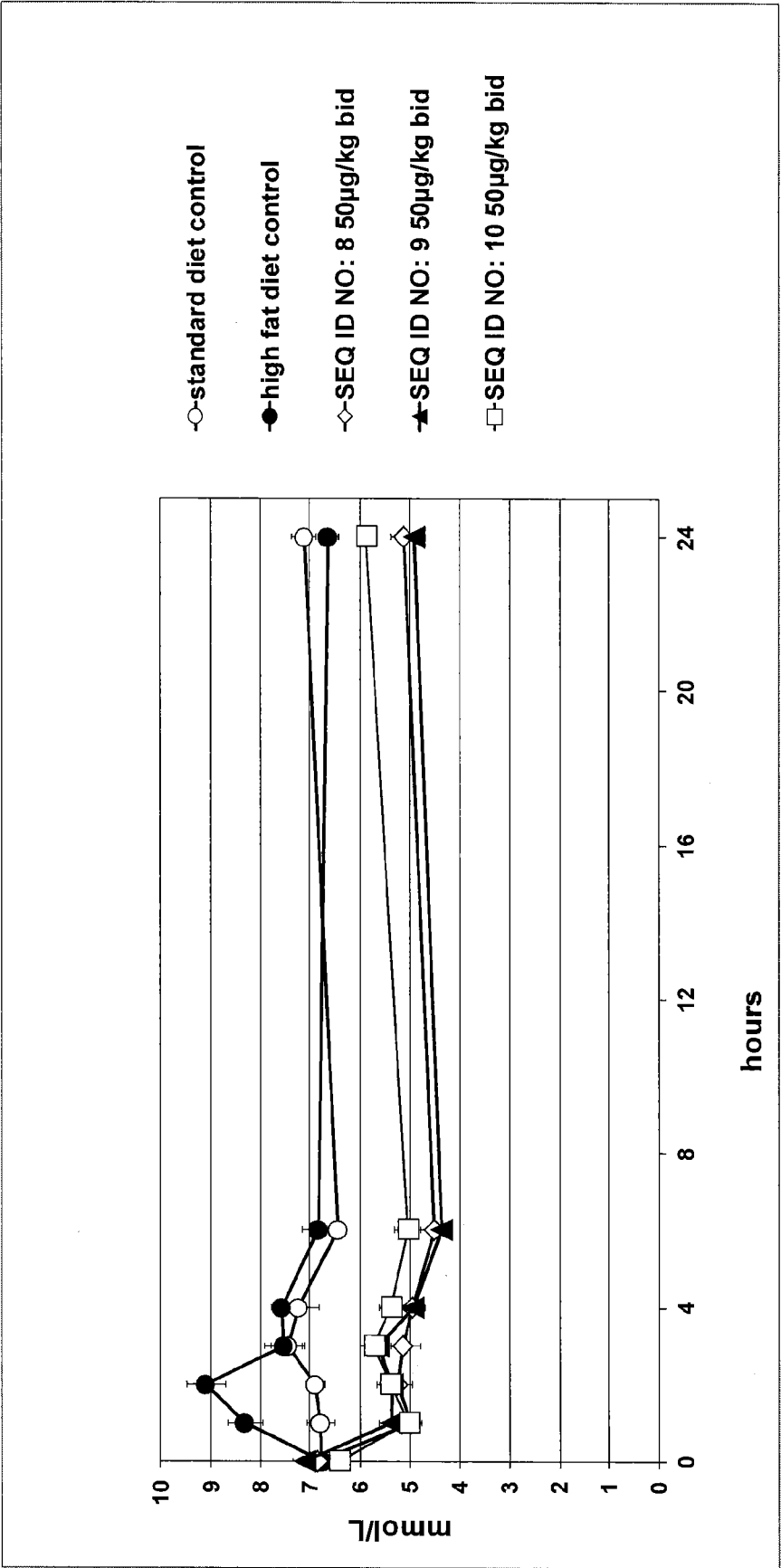


Fig. 7 b)

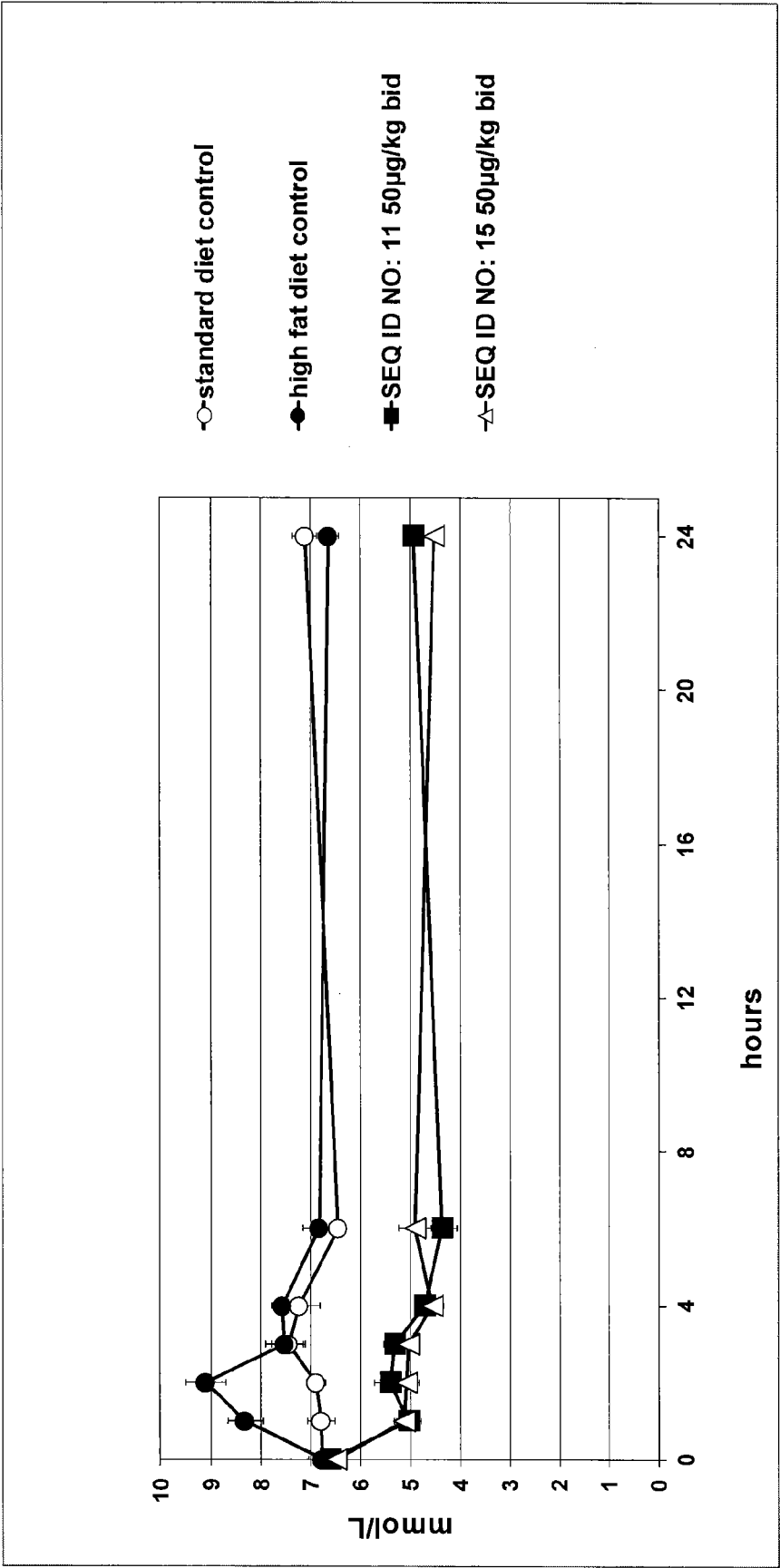


Fig. 8 a)

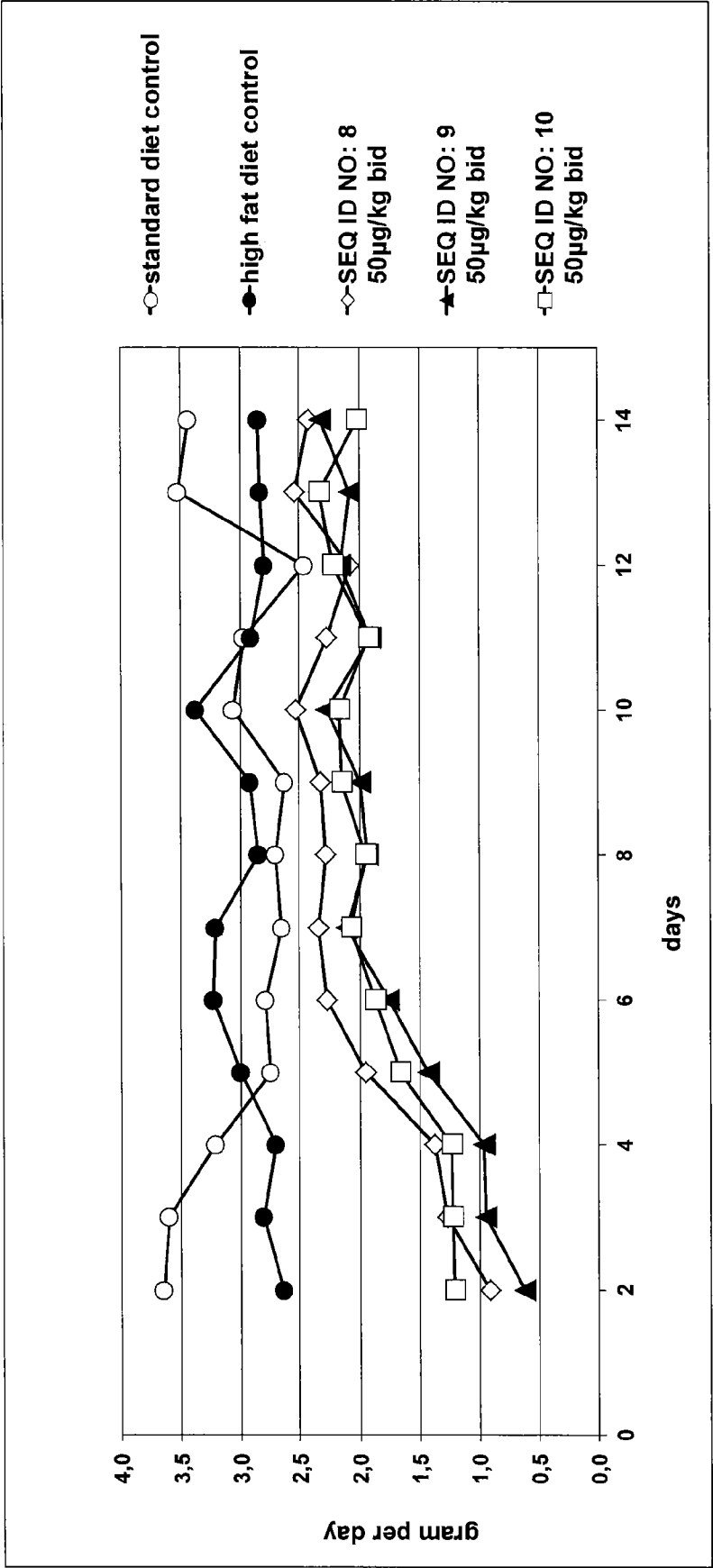
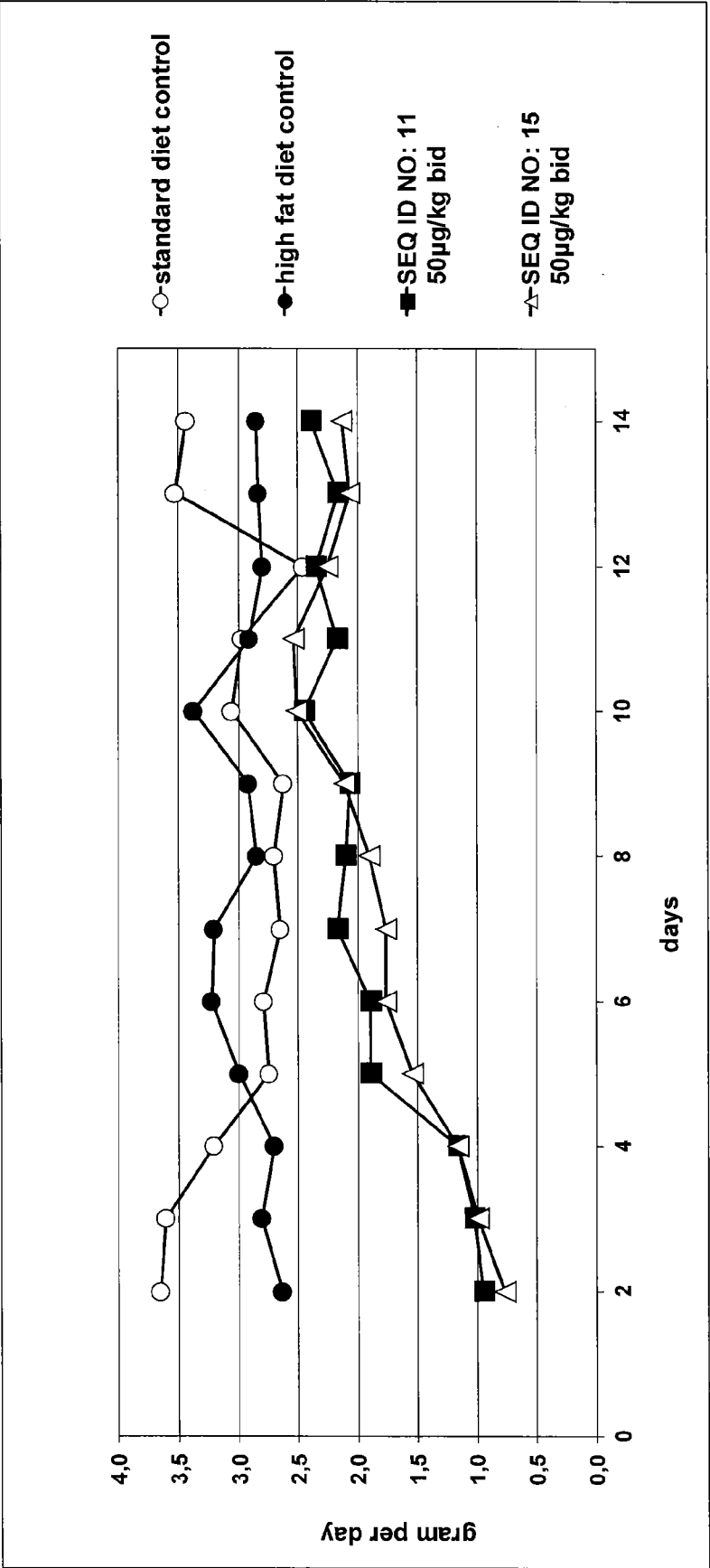


Fig. 8 b)



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Ser Gly Ala Pro Pro Pro Ser  
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 1 5 10 15

Ile His Gln Gln Asp Phe Val Asn Trp Leu Leu Ala Gln Lys Gly Lys  
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Lys Asn Asp Trp Lys His Asn Ile Thr Gln  
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Hi s Xaa Gl n Gly Thr Phe Thr Ser Asp Leu Ser Lys Gl n Lys Asp Gl u  
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Ser Xaa Lys Pro Pro Pro Lys  
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1 5 10 15

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Gln Arg Ala Lys Leu Phe Ile Glu Trp Leu Xaa Ala Gly Gly Pro Pro  
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Ser Xaa Lys Pro Pro Pro Lys  
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 20 25 30

Ser Xaa Lys Pro Pro Pro Lys  
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Gln Arg Ala Lys Leu Phe Ile Glu Trp Leu Xaa Ala Gly Gly Pro Pro  
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Ser Xaa Lys Pro Pro Pro Lys  
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Gln Arg Ala Lys Leu Phe Ile Glu Trp Leu Xaa Ala Gly Gly Pro Pro  
 20 25 30

Ser Xaa Lys Pro Pro Pro Lys  
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 1 5 10 15

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 20 25 30

Ser Xaa Lys Pro Pro Pro Lys  
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 20 25 30

Ser Xaa Lys Pro Pro Pro Lys  
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Gl n Arg Al a Lys Leu Phe Ile Gl u Trp Leu Lys Al a Gly Gly Pro Ser  
 20 25 30

Ser Gly Al a Pro Pro Pro Ser  
 35

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&lt;211&gt; 39

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 butyryl

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&lt;400&gt; 19

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 1 5 10 15

Gl n Arg Al a Lys Leu Phe Ile Gl u Trp Leu Lys Al a Xaa Gly Pro Ser  
 20 25 30

Ser Gly Al a Pro Pro Pro Ser  
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 1 5 10 15

Gln Arg Ala Lys Leu Phe Ile Glu Trp Leu Lys Ala Gly Gly Pro Ser  
 20 25 30

Ser Gly Ala Pro Pro Pro Ser  
 35