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(54) Titre : COMPOSITIONS RENFERMANT UNE ALPHA-MANNOSIDASE ET UTILISATIONS ASSOCIEES

(54) Title: COMPOSITIONS COMPRISING ALPHA MANNOSIDASE AND USES THEREOF

(57) Abrégé/Abstract:

The present invention comprises a method of concentrating a composition comprising a polypeptide of interest and the use of such a concentrated composition for the treatment of diseases in mammals, in particular by subcutaneous injection.



**ABSTRACT**

The present invention comprises a method of concentrating a composition comprising a polypeptide of interest and the use of such a concentrated composition for the treatment of diseases in mammals, in particular by 5 subcutaneous injection.

**COMPOSITIONS COMPRISING ALPHA MANNOSIDASE AND USES THEREOF****FIELD OF THE INVENTION**

The present invention relates to a method for concentrating a polypeptide of interest, to the use of a composition comprising a concentrated polypeptide of interest as a medicament for subcutaneous injection and to a composition comprising at least 10 mg/ml polypeptide of interest.

**BACKGROUND OF THE INVENTION**

10 Some polypeptides are useful as a medicament for the prevention and/or treatment of certain diseases. The ability to inject a medicament subcutaneously is an advantage as it makes it easy for the patients to administer the medication to themselves.

As there are physiological restraints on how large a volume it is possible to inject 15 subcutaneously. Thus it is an advantage for medicaments which are to be administered subcutaneously that they are available in a high concentration so as to ensure that the patient receives an adequate amount of the medicament and/or to avoid multiple subcutaneous injections.

WO 99/37325 discloses methods of treating and preventing disease caused by 20 absence or deficiency of the activity of enzymes belonging to the heme biosynthetic pathway. WO 03/002731 discloses a process for purification of recombinant porphobilinogen deaminase on an industrial scale and to the use of the purified product for the preparation of a medicament. Similarly, WO 02/099092 and WO 2005/094874 provides lysosomal alpha-mannosidase and 25 therapeutic use hereof. Finally, WO 2005/073367 provides a process for purification of aryl sulfatase A and use of the enzyme in the treatment of metachromatic leukodystrophy.

The present invention relates to a method for concentrating a polypeptide of interest and to the use of a composition comprising a concentrated polypeptide of 30 interest for the manufacture of a medicament for subcutaneous injection into mammal.

**SUMMARY OF THE INVENTION**

The present invention relates in one aspect to a method of concentrating a composition comprising a polypeptide of interest comprising:

- 5      a) Centrifugation and/or filtration of a composition comprising a polypeptide of interest
- b) Concentrating the supernatant or retentate, respectively, obtained from step a).

In another aspect the present invention relates to a composition comprising at least 10 mg/ml polypeptide of interest.

- 10     In yet another aspect the present invention relates to use of a composition comprising 75-250 mg/ml polypeptide of interest for the manufacture of a medicament for subcutaneous injection into a mammal.

In yet another aspect the present invention relates to a method of treating a mammal for Acute Intermittent Porphyria comprising injecting subcutaneously a composition of 500-300 mg/ml PBGD.

In yet another aspect the present invention relates a method of treating a mammal for metachromatic leukodystrophy comprising subcutaneous injection of a composition of 50-300 mg/ml aryl sulfatase A.

20     In yet another aspect the present invention relates a method of treating a mammal for the lysosomal storage disorder alpha-mannosidosis comprising subcutaneous injection of a composition of 50-300 mg/ml lysosomal alpha-mannosidase.

In yet another aspect the present invention relates a method of treating a mammal for Krabbe disease comprising subcutaneous injection of a composition 25 of 50-300 mg/ml galactosylcerebrosidase.

**DEFINTIONS**

For purposes of the present invention, alignments of sequences and calculation of homology scores may be done using a full Smith-Waterman alignment, useful for 30 both protein and DNA alignments. The default scoring matrices BLOSUM50 and the identity matrix are used for protein and DNA alignments respectively. The penalty for the first residue in a gap is - 12 for proteins and -16 for DNA, while the penalty for additional residues in a gap is -2 for proteins and -4 for DNA.

Alignment may be made with the FASTA package version v20u6 (W. R. Pearson and D. J. Lipman (1988), "Improved Tools for Biological Sequence Analysis", PNAS 85:2444-2448, and W. R. Pearson (1990) "Rapid and Sensitive Sequence Comparison with FASTP and FASTA", Methods in Enzymology, 183:63-98).

- 5 Multiple alignments of protein sequences may be made using "ClustalW" (Thompson, J. D., Higgins, D. G. and Gibson, T.J. (1994) CLUSTAL W: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, positions-specific gap penalties and weight matrix choice. Nucleic Acids Research, 22:4673-4680). Multiple alignment of DNA sequences may be done
- 10 using the protein alignment as a template, replacing the amino acids with the corresponding codon from the DNA sequence.

In the context of the present invention, the term "E. C." (Enzyme Class) refers to the internationally recognized enzyme classification system, Recommendations of the Nomenclature Committee of the International Union of Biochemistry and  
15 Molecular Biology, Academic Press, Inc.

The term "origin" used in the context of amino acid sequences, e.g. proteins, or nucleic acid sequences is to be understood as referring to the organism from which it derives. Said sequence may be expressed by another organism using gene technology methods well known to a person skilled in the art. This also  
20 encompasses sequences which have been chemically synthesized. Furthermore, said sequences may comprise minor changes such as codon optimization, i.e. changes in the nucleic acid sequences which do not affect the amino acid sequence.

## 25 DETAILED DESCRIPTION OF THE INVENTION

### Polypeptide of interest

The polypeptide of the present invention may in particular be a hormone or hormone variant, an enzyme, a receptor or portion thereof, an antibody or portion thereof, an allergen or a reporter. The polypeptide of interest may in particular be  
30 an enzyme selected from one of six major enzyme groups, such as an oxidoreductase (E.C. 1), a transferase (E.C. 2), a hydrolase (E.C. 3), a lyase (E.C. 4), an isomerase (E.C. 5), or a ligase (E.C. 6). In a more particular aspect, the polypeptide of interest may be an aminopeptidase, amylase, carbohydrolase, carboxypeptidase, catalase, cellulase, cellobiohydrolase, chitinase, cutinase,  
35 cyclodextrin glycosyltransferase, deoxyribonuclease, endoglucanase, esterase,

alpha-galactosidase, beta-galactosidase, glucoamylase, alpha-glucosidase, beta-glucosidase, invertase, laccase, lipase, mannosidase, mutanase, oxidase, pectinolytic enzyme, peroxidase, phospholipase, phytase, polyphenoloxidase, proteolytic enzyme, ribonuclease, transglutaminase, xylanase, or beta-xylosidase.

5 The polypeptide of interest may in particular be a polypeptide which is useful as a medicament.

Examples of a suitable polypeptide of interest include but is not limited to one selected from the group consisting of a phosphobilinogen deaminase, an aryl sulfatase, an alpha-mannosidase and a galactocerebrosidase.

10 In principle a polypeptide of interest derivable from any source may be treated according to the methods of the present invention.

In a particular embodiment the polypeptide of interest may be of human origin. Especially in the context of using a polypeptide of interest for the manufacture of a medicament which is to be administered to humans may the polypeptide be of 15 human origin as this may minimize the risk of unwanted allergic reactions. Natural variations of human polypeptide due to e.g. polymorphism are in the context of the present invention included in the term "human origin".

The polypeptide of interest may in particular be produced as a recombinant protein, i.e. a nucleotide sequence encoding the polypeptide of interest may be 20 introduced into a cell for expression of the polypeptide of interest. The recombinant expression may be homologous or heterologous, i.e. the polypeptide of interest may be expressed in cell which it is naturally expressed by (homologous expression) or it may be expressed by a cell which it is not naturally expressed by (heterologous expression).

25 The recombinant polypeptide of interest may be expressed by any cell suitable for recombinant production of the particular polypeptide of interest. Examples of suitable cells include but are not limited to prokaryotic cells, such as an *E.coli* cell or a *Bacillus* cell. Examples of suitable eukaryotic cells include but are not limited to a yeast cell or a mammalian cell such as a Chinese Hamster Ovary (CHO).

30 Alternatively, it may be a human cell.

Suitable host cells for the expression of glycosylated polypeptide are derived from multicellular organisms. Examples of invertebrate cells include plant and insect cells. However, the host cell may also be a vertebrate cell, and propagation of vertebrate cells in culture (tissue culture) has become a routine procedure

The term "recombinant polypeptide" or "recombinant polypeptide of interest" denotes herein a recombinant produced polypeptide.

Reference to a particular polypeptide of interest includes in the context of the present invention also functionally equivalent parts or analogues of the

5 polypeptide of interest. For example, if the polypeptide of interest is an enzyme a functionally equivalent part of the enzyme could be a domain or subsequence of the enzyme which includes the necessary catalytic site to enable the domain or subsequence to exert substantially the same enzymatic activity as the full-length enzyme or alternatively a gene coding for the catalyst. The term "substantially the 10 same enzymatic activity" refers to an equivalent part or analogue having at least 50%, preferably at least 60%, more preferably at least 70%, more preferably at least 75%, more preferably at least 80%, more preferably at least 85%, more preferably at least 90%, more preferably at least 95% and most preferably at least 97%, at least 98% or at least 99% of the activity of the natural enzyme. An 15 example of an enzymatically equivalent analogue of the enzyme could be a fusion protein which includes the catalytic site of the enzyme in a functional form, but it can also be a homologous variant of the enzyme derived from another species. Also, completely synthetic molecules that mimic the specific enzymatic activity of the relevant enzyme would also constitute "enzymatic equivalent analogues".

20 Generally, the skilled person will be able to readily devise appropriate assays for the determination of enzymatic activity. For PBGD, however, a suitable assay is described in WO 03/002731, in example 2, as well as in the experimental sections of the present applications. Aryl sulfatase, in addition to its natural substrates, is also able to catalyze the hydrolysis of the synthetic, chromogenic substrate, para- 25 Nitrocatechol sulfate (pNCS). The product, para-Nitrocatechol (pNC), absorbs light at 515 nm. An assay for determination of aryl sulfatase activity is described in details in WO 2005/073367 and in Fluharty et al. 1978, Meth. Enzymol. 50:537-47. For LAMAN, an appropriate enzyme activity assay is disclosed in WO 02/099092.

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Porphobilinogen deaminase

In one embodiment the polypeptide of interest of the invention may be porphobilinogen deaminase, (also known as porphobilinogen ammonia-lyase (polymerizing)), E.C. 4.3.1.8. (Waldenström 1937, J. Acta.Med. Scand. Suppl.8). 35 Porphobilinogen deaminase is the third enzyme in the heme biosynthetic pathway. E.C. 4.3.1.8 has been transferred to E.C. 2.5.1.61, so porphobilinogen deaminase (PBGD) is now placed under this E.C. number.

Porphobilinogen deaminase catalyzes the reaction of 4 porphobilinogen + H<sub>2</sub>O = hydroxymethylbilane + 4 NH<sub>3</sub>.

PBDG is important in relation to Acute intermittent porphyria (AIP), which is an autosomal dominant disorder in man caused by a defect (50% reduction of 5 activity) of PBDG (see WO01/07065 for further details in relation to this).

Porphobilinogen deaminase is in short known as PBGD and in the context of the present invention these two terms may be used inter-changeably with one another.

For recombinant expression of PBGD a host cell may in particular be a yeast cell 10 or an *E.coli* cell.

For a detailed example of construction of a recombinant *E.coli* cell reference is made to example 1 of WO01/07065 and for construction of recombinant HeLa cells and NIH 3T3 cells capable of expressing mouse PBGD reference is made to example 6 of WO01/07065.

15 The term "recombinant porphobilinogen deaminase (rPBGD)" denotes herein a recombinant produced PBGD. In the following, this enzyme and the recombinant human form will be termed "PBGD" and "rhPBGD", respectively. Within this term is also included an enzymatically equivalent part or analogue of PBGD. One example of an enzymatically equivalent part of the enzyme could be a domain or 20 subsequence of the enzyme which includes the necessary catalytic site to enable the domain or subsequence to exert substantially the same enzymatic activity as the full-length enzyme or alternatively a gene coding for the catalyst. The term "substantially the same enzymatic activity" refers to an equivalent part or analogues enzyme having at least 50%, preferably at least 60%, more preferably at least 70%, more preferably at least 75%, more preferably at least 80%, more 25 preferably at least 85%, more preferably at least 90%, more preferably at least 95% and most preferably at least 97%, at least 98% or at least 99% of the activity of natural human rhPBGD measured in the rhPBGD activity assay described in example 2 of WO 03/002731. An example of an enzymatically 30 equivalent analogue of the enzyme could be a fusion protein which includes the catalytic site of the enzyme in a functional form, but it can also be a homologous variant of the enzyme derived from another species. Also, completely synthetic molecules that mimic the specific enzymatic activity of the relevant enzyme would also constitute "enzymatic equivalent analogues".

An example of PBGD which may be used in the present invention includes any of those shown in Sequence 1-10 of the present application, or in Genebank no. X04217, X04808 or M95623.

Aryl sulfatase

5 In another embodiment of the present invention the polypeptide of interest may be an arylsulfatase A.

Arylsulfatase A catalyzes the reaction of a cerebroside 3-sulfate + H<sub>2</sub>O = a cerebroside + sulphate.

ASA has been purified from a variety of sources including human liver, placenta, 10 and urine. It is an acidic glucoprotein with a low isoelectric point. Above pH 6.5, the enzyme exists as a dimer with a molecular weight of approximately 110 kDa. ASA undergoes a pH-dependent polymerisation forming an octamer at pH 4.5. In human urine, the enzyme consists of two nonidentical subunits of 63 and 54 kDa. ASA purified from human liver, placenta, and fibroblasts also consist of two 15 subunits of slightly different sizes varying between 55 and 64 kDa. As in the case of other lysosomal enzymes, ASA is synthesised on membrane-bound ribosomes as a glycosylated precursor. It then passes through the endoplasmic reticulum and Golgi, where its N-linked oligosaccharides are processed with the formation of phosphorylated and sulfated oligosaccharide of the complex type (Waheed A et al. 20 Biochim Biophys Acta. 1985, 847, 53-61, Braulke T et al. Biochem Biophys Res Commun. 1987, 143, 178-185). In normal cultured fibroblasts, a precursor polypeptide of 62 kDa is produced, which translocates via mannose-6-phosphate receptor binding (Braulke T et al. J Biol Chem. 1990, 265, 6650-6655) to an acidic prelysosomal endosome (Kelly BM et al. Eur J Cell Biol. 1989, 48, 71-78).

25 The arylsulfatase A may in particular be of human origin. The length (18 amino acids) of the human ASA signal peptide is based on the consensus sequence and a specific processing site for a signal sequence. Hence, from the deduced human ASA cDNA (EMBL GenBank accession numbers J04593 and X521151) the cleavage of the signal peptide should be done in all cells after residue number 18 (Ala), 30 resulting in the mature form of the human ASA. In the following, recombinant arylsulfatase A will be abbreviated rASA, the mature form of arylsulfatase A including the mature form of human ASA will be termed "mASA" and the mature recombinant human ASA will be termed "mrhASA".

A protein modification has been identified in two eukaryotic sulfatases (ASA and 35 arylsulfatase B (ASB)) and for one from the green alga *Volvox carteri* (Schmidt B et al. Cell. 1995, 82, 271-278, Selmer T et al. Eur J Biochem. 1996, 238, 341-

345). This modification leads to the conversion of a cysteine residue, which is conserved among the known sulfatases, into a 2-amino-3-oxopropionic acid residue (Schmidt B et al. *Cell*. 1995, 82, 271-278). The novel amino acid derivative is also recognised as C\*-formylglycin (FGly). In ASA and ASB derived 5 from MSD cells, the Cys-69 residue is retained. Consequently, it is proposed that the conversion of the Cys-69 to FGly-69 is required for generating catalytically active ASA and ASB, and that deficiency of this protein modification is the cause of MSD. Cys-69 is referred to the precursor ASA which has an 18 residue signal peptide. In the mASA the mentioned cysteine residue is Cys-51. Further 10 investigations have shown that a linear sequence of 16 residues surrounding the Cys-51 in the mASA is sufficient to direct the conversion and that the protein modification occurs after or at a late stage of co-translational protein translocation into the endoplasmic reticulum when the polypeptide is not yet folded to its native structure (Dierks T et al. *Proc Natl Acad Sci*. 1997, 94, 11963-1196, Wittke, D. et 15 al. (2004), *Acta Neuropathol. (Berl.)*, 108, 261-271).

Multiple forms of ASA have been demonstrated on electrophoresis and isoelectric focusing of enzyme preparations from human urine, leukocytes, platelets, cultured fibroblasts and liver. Treatment with endoglycosidase H, sialidase, and alkaline phosphatase reduces the molecular size and complexity of the electrophoretic 20 pattern, which suggests that much of the charge heterogeneity of ASA is due to variations in the carbohydrate content of the enzyme.

The arylsulfatase A may in particular be a form of arylsulfatase A, which is capable of crossing the blood brain barrier and/or a form of rASA, which possesses specific tags for entry into target cells within the brain. In particular, it may be a rASA, 25 which is efficiently endocytosed in vivo via the mannose-6-phosphate pathway.

Thus the ASA may in particular be covalently bound to a so-called tag, peptides or proteins as vehicles or toxins as vehicles which are capable of increasing and/or facilitating transport of ASA over the blood-brain barrier and/or across cellular membranes in general (Schwarze et al., *Trends Cell Biol*. 2000; 10(7): 290-295; 30 Lindgren et al., *Trends Pharmacol. Sci*. 2000; 21(3): 99-103). An ASA molecule containing such peptide sequences can be produced by expression techniques. The protein transduction process is not cell type specific and the mechanism by which it occurs is not fully elucidated, however, it is believed that it takes place by some sort of membrane perturbation and penetration process that is receptor 35 independent. A partially unfolded state of the molecule may facilitate the process but is not essential.

An example of a suitable tag includes but is not limited to the mannose-6-phosphate tag.

Examples of peptides or proteins as vehicle include but are not limited to so-called protein-transducing domains. Examples of suitable protein-transducing domains include but are not limited to those mentioned in WO 2005/073367. Hence the protein-transducing domain may be the 11 residue basic peptide from the HIV

5 TAT protein -YGRKKRRQRRR (Schwarze et al., Trends Cell Biol. 2000; 10(7): 290-295), a synthetic version of TAT -YARAAARQARA that confers more alpha-helicity and amphipathic nature to the sequence (Ho et al., Cancer Res. 2001; 61(2):474-477), a synthetic leader peptide composed of poly -R or a mixture of basic -R and -K residues in combination with other amino acids and peptides based on  
 10 hydrophobic signal sequence moieties from either beta-3 integrin or Kaposi's sarcoma FGF (Duncan et al. Biopolymers 2001; 60(1): 45-60).

Examples of suitable toxins as vehicles include but are not limited to those described in WO 2005/073367.

The ASA may in particular comprise a nucleic acid sequence, which encodes:

15 (a) the amino acid sequence of SEQ ID NO:2 in WO 2005/073367;  
 (b) a portion of the sequence in (a), which is enzymatically equivalent to recombinant human arylsulfatase A  
 (c) an amino acid sequence analogue having at least 75% sequence identity to any one of the sequences in (a) or (b) and at the same time comprising an  
 20 amino acid sequence, which is enzymatically equivalent to recombinant human arylsulfatase A.

In the present context, an amino acid sequence or a portion of an amino acid sequence which is a polypeptide capable of hydrolysing an amount of the arylsulfatase A substrate pNCS at 37°C a rate corresponding to a specific activity  
 25 of at least 20 U/mg polypeptide (preferably 50 U/mg polypeptide) when determined in an assay for measuring arylsulfatase A activity as described in example 1 of WO 2005/073367, and/or a polypeptide, which is capable of hydrolysing at least 40% of labelled arylsulfatase A substrate, fx. <sup>14</sup>C palmitoyl sulfatide, loaded into MLD fibroblasts, when assayed by incubation at a dose level  
 30 of 25 mU/ml in an assay as described in example 2 of WO 2005/073367.

The ASA may in another embodiment in particular comprise:

(a) the nucleic acid sequence of SEQ ID NO:1 in WO 2005/073367  
 (b) a portion of the sequence in (a), which encodes an amino acid sequence, which is enzymatically equivalent to recombinant human arylsulfatase A  
 35 (c) a nucleic acid sequence analogue having at least 75% sequence identity to any one of the sequences in (a) or (b) and at the same time

encoding an amino acid sequence, which is enzymatically equivalent to recombinant human arylsulfatase A

It may be preferred that the degree of sequence identity between the above mentioned nucleic acid sequence and SEQ ID NO: 1 of WO 2005/073367 is at least 80%, such as at least 85%, at least 90%, at least 95%, at least 97%, at least 98%, or at least 99%. It may be equally preferred that the degree of sequence identity between the amino acid sequence encoded by the above mentioned nucleic acid sequence and SEQ ID NO: 2 WO 2005/073367 is at least 80%, such as at least 85%, at least 90%, at least 95%, at least 97%, at least 98%, or at least 99%.

For the purpose of the present invention it is preferred that the arylsulfatase A is a recombinant enzyme, particularly preferred is recombinant human arylsulfatase A (rhASA).

It is preferred that rASA is produced in a mammalian cell or cell line and that said mammalian cell or cell line produces a glycoform of rASA, which is efficiently endocytosed in vivo via the mannose-6-phosphate receptor pathway. Specifically, the preferred glycoform of rASA comprises an amount of exposed mannose-6-phosphate, which allows efficient endocytosis of rASA in vivo via the mannose-6-phosphate pathway.

20 In a particular embodiment at least one of the produced glycoforms of rASA is similar to a glycoform produced in CHO cells.

The post translational modification of the cysteine residue in position 51 in the mature human arylsulfatase A is relevant for the activity of the enzyme.

Accordingly, in a preferred embodiment of the present invention production of the 25 arylsulfatase A or its equivalent occurs at a rate and under conditions, which result in a product comprising an isoform of the enzyme in which the amino acid corresponding to Cys-69 in SEQ ID NO: 2 of WO 2005/073367 is converted to Formylglycine, corresponding to Fgly-51 in SEQ ID NO: 3 of WO 2005/073367. SEQ ID NO: 4 of WO 2005/073367 represents mature human arylsulfatase A after 30 cleavage of the 18 amino acid signal peptide but prior to modification of C-51.

Thus in another embodiment of the present invention the ASA or its enzymatical equivalent may be selected from the group consisting of

- (a) the amino acid sequence of SEQ ID NO:3 of WO 2005/073367;
- (b) a portion of the sequence in (a), which is enzymatically equivalent to 35 recombinant human arylsulfatase A

- (c) an amino acid sequence analogue having at least 75% sequence identity to any one of the sequences in (a) or (b) and at the same time being enzymatically equivalent to recombinant human arylsulfatase A.

It may be preferred that the degree of sequence identity between the enzyme 5 produced according to the invention and SEQ ID NO: 3 of WO 2005/073367 or SEQ ID NO: 4 of WO 2005/073367 is at least 80%, such as at least 85%, at least 90%, at least 95%, at least 97%, at least 98%, or at least 99%.

For the biological activity and the effects of the enzyme *in vivo* requires to be 10 optimal it is an advantage if an adequate amount of the enzyme has acquired a glycosylation pattern as described above and has been modified post translationally at position 51. Thus at least 50%, 60%, 70%, 80%, 90%, 95% or 98% of the ASA of the present invention may be in the above described glycoform/isoform.

The ASA of the present invention may in terms of its structure be different from 15 the rASA according to SEQ ID NO: 3 of 2005/073367. It may be an advantage that the sequence of amino acid residues surrounding the Cys-51 is identical or has a high degree of sequence identity to the corresponding sequence in SEQ ID NO: 3. Thus, it may be preferred that a linear sequence of 20 amino acids, such as 19, 18, 17, 16, 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5 or 4 amino acid residues 20 surrounding the Cys-51 in the arylsulfatase A is identical or at least 90% identical, such as 95%, 96%, 97%, 98%, or 99% identical to the corresponding sequence in SEQ ID NO: 3 of 2005/073367. As the active form of rASA within the lysosomes is an octamer the ASA of the present invention may in particular be a rASA which is an octamer or assembles into an octamer under physiological conditions.

25 The enzyme activity of ASA, which is to be understood as the catalytic activity of the rASA, may be measured in an enzyme assay based on the rASA mediated hydrolysis of either a detectable substrate or a substrate, which leads to a detectable end product. In a preferred aspect the assay is based on hydrolysis of the synthetic, chromogenic substrate, para-Nitrocatechol sulphate (pNCS) which 30 has an end product, para-Nitrocatechol (pNC) that absorbs light at 515 nm.

#### Lysosomal alpha-mannosidase

In yet another embodiment the polypeptide of interest may be a lysosomal alpha-mannosidase (LAMAN). Lysosomal alpha-mannosidase belongs to EC 3.2.1.24 and is an exoglycosidase which hydrolyses the terminal, non-reducing alpha-D-mannose 35 residues in alpha-D-mannosides from the non-reducing end during the ordered degradation of N-linked glycoproteins (Aronson and Kuranda FASEB J 3:2615-

2622. 1989). In the context of the present invention the term lysosomal alpha-mannosidase may be used interchangeably with the short term LAMAN.

The LAMAN of the present invention may in particular be of human origin. The human enzyme is synthesised as a single polypeptide of 1011 amino acids with a 5 putative signal peptide of 49 residues that is processed into three main glycopeptides of 15, 42, and 70 kD (Nilssen et al. *Hum.Mol.Genet.* 6, 717-726. 1997).

The gene coding for LAMAN (MANB) is located at chromosome 19 (19cen-q12), (Kaneda et al. *Chromosoma* 95:8-12. 1987). MANB consists of 24 exons, 10 spanning 21.5 kb (GenBank accession numbers U60885-U60899; Riise et al. *Genomics* 42:200-207. 1997). The LAMAN transcript is ≈ 3,500 nucleotides (nts) and contains an open reading frame encoding 1,011 amino acids (GenBank U60266.1).

The cloning and sequencing of the human cDNA encoding LAMAN has been 15 published in three papers (Nilssen et al. *Hum.Mol.Genet.* 6, 717-726. 1997; Liao et al. *J.Biol.Chem.* 271, 28348-28358. 1996; Nebes et al. *Biochem.Biophys.Res.Commun.* 200, 239-245. 1994). Curiously, the three sequences are not identical. When compared to the sequence of Nilssen et al 20 (accession # U60266.1) a TA to AT change at positions 1670 and 1671 resulting in a valine to aspartic acid substitution was found by Liao et al. and Nebes et al.

In a most preferred embodiment, the lysosomal alpha mannosidase comprises the amino acid sequence of SEQ ID NO.: 1 of WO 2005/094874.

For practical and economical reasons it is preferred that the LAMAN of the present invention is produced recombinant. By recombinant production it may also be 25 possible to obtain a preparation of the enzyme wherein a large fraction contains mannose-6-phosphate. Recombinant production may be achieved after transfection of a cell using a nucleic acid sequence comprising the sequence of SEQ ID NO: 2 of WO 2005/094874.

The alpha-mannosidase is preferably made in a mammalian cell system as this 30 will result in a glycosylation profile, which ensures efficient receptor mediated uptake in cells of for instance visceral organs of the body. In particular, it has been found that production of the enzyme in CHO, COS or BHK cells ensures adequate post-translational modification of the enzyme by addition of mannose-6-phosphate residues. In addition a correct sialylation profile is obtained. Correct 35 sialylation is known to be important in order to prevent uptake by the liver, because of exposed galactose residues.

In even more preferred embodiments the mammalian cell system is therefore selected from the group comprising CHO, COS cells or BHK cells (Stein et al. J Biol Chem. 1989, 264, 1252-1259). It may further be preferred that the mammalian cell system is a human fibroblast cell line.

5 In a most preferred embodiment, the mammalian cell system is a CHO cell line.

In another embodiment the lysosomal alpha-mannosidase may be a preparation of lysosomal alpha-mannosidase wherein a fraction of said preparation consists of lysosomal alpha mannosidase having one or more N-linked oligosaccharides carrying mannose 6-phosphate groups.

10 It is further preferred that a fraction of a preparation of said lysosomal alpha-mannosidase is capable of binding to mannose 6-phosphate receptors.

The ability of the enzyme to bind to mannose-6-phosphate receptors may be determined in an in vitro assay as described in example 1 of WO 2005/094874. Here, binding of the enzyme to a MPR affinity 300 Matrix provides a measure of 15 its ability to bind to mannose-6-phosphate receptors. In a preferred embodiment of the invention binding of the enzyme to mannose-6-phosphate receptors occurs in vitro.

In more preferred embodiments of the invention this fraction corresponds to from 1 to 75% of the activity of a preparation of lysosomal alpha-mannosidase, such as 20 from 2 to 70%, such as from 5 to 60%, such as from 10 to 50% such as from 15 to 45%, such as from 20 to 40%, such as from 30 to 35%.

Accordingly, it is preferred that the lysosomal alpha-mannosidase has a content of mannose 6-phosphate residues allowing mannose 6-phosphate dependent binding of from 2 to 100%, 5 to 95%, 10 to 90%, 20 to 80%, 30 to 70% or 40 to 60% of 25 the amount of enzyme to a Man-6-P-receptor matrix. At present, the degree of phosphorylation has been analysed in several batches of enzyme and, typically, from 30 to 45% of the enzyme is phosphorylated and binds the affinity matrix.

It is further preferred that a fraction constituting from 2 - 100%, 5 - 90%, 10 - 80%, 20 - 75%, 30 - 70%, 35 - 65% or 40 - 60% of the amount of said 30 lysosomal alpha-mannosidase binds to the Man-6-P-receptor with high affinity. Theoretically, two mannose 6-phosphate groups must be positioned close to each other in order for the enzyme to bind a Man-6-P-receptor with high affinity. Recent observations suggest that the distance between the phosphorylated 35 mannose residues must be 40 Å or less in order to obtain high affinity binding. In the human lysosomal alpha-mannosidase according to SEQ ID NO: 1 of WO

2005/094874 the two mannose 6-phosphate residues may be situated at the asparagines residues in positions 367 and 766. Accordingly, it is preferred that the medicament according to the present invention comprises lysosomal alpha-mannosidase, a fraction of which carries mannose 6-phosphate groups at both of 5 these asparagine residues.

Preferably, the alpha-mannosidase is made by recombinant techniques. In a further embodiment, the alpha-mannosidase is of human origin (hLAMAN) and still more preferred a mature human alpha-mannosidase (mhLAMAN) or a fragment thereof. The fragment may be modified, however the active sites of the enzyme 10 should be preserved.

It is to be expected that, in preparations of alpha-mannosidase according to the present invention, one fraction of the enzyme is represented by its precursor form, while other fractions represent the proteolytically processed forms of approximately 55 and 70 kDa.

15 Galactocerebrosidase

In another embodiment the polypeptide of interest may be a galactocerebrosidase, which may be shortened to GALC. Galactocerebrosidase belongs to E.C. 3.1.6.46 and are enzymes capable of catalysing the reaction of D-galactosyl-N-acylsphingosine + H<sub>2</sub>O = D-galactose + N-acylsphingosine, thus 20 GALC catalyzes the degradation of galactolipids in for example myelin.

The GALC enzyme derived from humans is a glycosylated lysosomal enzyme comprising 643 amino acids and with a molecular weight of 72.8 kDa. The GALC of the present invention may in particular be of human origin. In a further embodiment the GALC may be expressed recombinant in one of the previously 25 mentioned host cells. The host cell for recombinant expression of GALC may in particular be a CHO cell.

In the description and in the claims reference is made to the following amino acid and nucleic acid sequences:

Sequence description	Sequence identifier
PBGD coding sequence 1	SEQ ID NO.: 1
PBGD coding sequence 2	SEQ ID NO.: 2
PBGD coding sequence 3	SEQ ID NO.: 3
PBGD coding sequence 4	SEQ ID NO.: 4
PBGD coding sequence 5	SEQ ID NO.: 5
PBGD coding sequence 6	SEQ ID NO.: 6

PBGD coding sequence 7	SEQ ID NO.: 7
PBGD coding sequence 8	SEQ ID NO.: 8
PBGD coding sequence 9	SEQ ID NO.: 9
PBGD coding sequence 10	SEQ ID NO.: 10
PBGD coding sequence, GenBank Acc. No. X04217	SEQ ID NO.: 11
PBGD coding sequence, GenBank Acc. No. X04808	SEQ ID NO.: 12
PBGD coding sequence, GenBank Acc. No. M95623	SEQ ID NO.: 13
PBGD aa sequence from coding sequence, GenBank Acc. No. M95623, Constitutive form	SEQ ID NO.: 14
PBGD aa sequence from coding sequence, GenBank Acc. No. M95623, Erythropoietic form	SEQ ID NO.: 15
ASA coding sequence Genbank Acc. No. J04593	SEQ ID NO.: 16
ASA coding sequence SEQ ID NO.: 1 of WO 2005/073367	SEQ ID NO.: 17
ASA aa sequence SEQ ID NO.: 2 of WO 2005/073367	SEQ ID NO.: 18
ASA aa sequence SEQ ID NO.: 3 of WO 2005/073367	SEQ ID NO.: 19
ASA aa sequence SEQ ID NO.: 4 of WO 2005/073367	SEQ ID NO.: 20
LAMAN aa sequence SEQ ID NO.: 1 of WO 2005/094874	SEQ ID NO.: 21
LAMAN coding sequence SEQ ID NO.: 1 of WO 2005/094874	SEQ ID NO.: 22
Galactocerebrosidase coding sequence	SEQ ID NO.: 23
Galactocerebrosidase aa sequence	SEQ ID NO.: 24

With reference to these sequences the polypeptide of interest, according to preferred embodiments of the invention, comprises an amino acid selected from the group consisting of:

- i) an amino acid sequence as defined by any of SEQ ID NO.s: 14, 15, 18, 19, 5 20, 21 and 24;
- ii) a functionally equivalent part of an amino acid sequence as defined in i); and
- iii) a functionally equivalent analogue of an amino acid sequence as defined in i) or ii), the amino acid sequence of said analogue being at least 75% identical to an amino acid sequence as defined in i) or ii).

10 In particular embodiments the analogue in iii) is at least 80% identical to a sequence as defined in i) or ii), such as at least 85%, at least 90%, at least 95%, at least 98%, at least 99%, or such as at least 99.5% identical to a sequence as defined in i) or ii).

Further, the polypeptide of interest may be obtained by recombinant expression using a nucleic acid sequence comprising a sequence selected from the group consisting of:

- 5 i) a nucleic acid sequence as defined by any of SEQ ID NO.s: 1-13, 16, 17, 22 and 23;
- ii) a nucleic acid sequence which is at least 75% identical to a nucleic acid sequence as defined in i).

For recombinant production of the polypeptide it may further be preferred that the acid sequence in ii) is at least 80% identical to a sequence as defined in i), such 10 as at least 85%, at least 90%, at least 95%, at least 98%, at least 99%, or such as at least 99.5% identical to a sequence as defined in i).

### **Composition comprising a polypeptide of interest**

The following description of a composition comprising a polypeptide of interest 15 relates both to a composition comprising a polypeptide which is concentrated according to a method of the present invention and it also relates to a composition of the present invention comprising at least 10 mg/ml polypeptide of interest.

The present invention also relates to a composition comprising at least 10 mg/ml polypeptide of interest, wherein the polypeptide of interest may be any 20 polypeptide according to the present invention, such as in particular rhPBGD, aryl sulfatase, alpha-mannosidase or galactocerebrosidase. Said composition may in particular comprise at least 25 mg/ml polypeptide of interest, such as at least 50 mg/ml or at least 75 mg/ml or at least 100 mg/ml polypeptide of interest. Thus said composition may in particular comprise between 10-1000 mg/ml polypeptide 25 of interest, such as between 10-500 mg/ml or between 10-300 mg/ml or between 10-200 mg/ml or between 25-500 mg/ml or between 25-400 mg/ml or between 40-400 mg/ml or between 40-300 mg/ml or between 50-400 mg/ml or between 50-300 mg/ml or between 75-400 mg/ml or between 75-300 mg/ml or between 100-200 mg/ml or between 100-150 mg/ml polypeptide of interest.

30 The composition comprising a polypeptide of interest may in particular be an aqueous solution.

Besides comprising a high concentration of polypeptide of interest said 35 composition may in particular further comprise no aggregates of the polypeptide of interest or at least only very few aggregates. Hence the amount of polypeptide of interest present as aggregates may in particular constitute less than 5 w/w% of the total amount of polypeptide of interest in the composition. In particular said

aggregates may constitute less than 4 w/w%, such as less than 3 w/w%, or less than 2 w/w%, or less than 1 w/w%, or less than 0.5 w/w%, or less than 0.1 w/w% of the total amount of polypeptide of interest. In the present context the term "aggregates" means any form of the polypeptide of interest which is not 5 monomeric. Thus the term encompasses any dimer or multimer of the polypeptide of interest.

Furthermore, it is an advantage if said composition comprises only the polypeptide of interest or at least only minor traces of other proteins, i.e. proteins different from polypeptide of interest. Hence in a particular embodiment said 10 composition comprises less than 1 w/w%, such as less than 0.5 w/w%, or less than 0.1 w/w%, or less than 0.05 w/w%, or less than 0.01 w/w% other proteins than the polypeptide of interest.

A range of factors affect the stability and activity of polypeptides and the composition comprising a polypeptide of interest may therefore in particular be 15 optimized to keep the polypeptide of interest as stable as possible.

The pH generally affects the stability of a polypeptide of interest, thus the pH of a composition comprising a polypeptide of interest may in particular be in the range of 7.5-8.5, such as in particular between pH 7.7-8.2, more particularly between pH 7.8-8.0 or between pH 7.85-7.95, such as pH 7.8 or pH 7.9. This may in 20 particular be the case if the polypeptide of interest is PBGD.

Thus the composition comprising a polypeptide of interest may in particular comprise a buffer capable of keeping the composition within the described pH range. Examples of such buffers include but are not limited to TRIS-HCL, Na-Citrate and Na<sub>2</sub>HPO<sub>4</sub>. The concentration of such a buffer may depend on the 25 choice of the particular buffer and the presence of other components in the composition. If the buffer is Na<sub>2</sub>HPO<sub>4</sub> the concentration of Na<sub>2</sub>HPO<sub>4</sub> may be in the range of 0.5-15 mM, such as in the range of 1-10 mM, or in the range of 1.5-7.5 mM, such as in the range of 1.83-7.4 mM, or in the range of 1.5-3 mM, such as in the range of 1.83-3.7 mM, or in the range of 1.83-2.45 mM, or in the range of 30 3.5-7.5 mM, such as in the range of 3.6-7.4 mM, or in the range of 5.4-7.4 mM, such as 1.84 mM, or 2.45 mM, or 3.67 mM or 5.51 mM or 7.34 mM.

If the buffer is TRIS-HCL the concentration of TRIS-HCL may in particular be in the range of 2-50 mM, such as 2-40 mM, or 2-30 mM, or 2-20 mM, or 2-10 mM, or 5-25 mM, or 5-20 mM, or 8-12 mM, or 9-11 mM, e.g. 10 mM.

35 Examples of other compounds which the composition comprising a polypeptide of interest may comprise include but are not limited to amino acids, sugars, alcohols

and detergents. Examples of such suitable compounds include but are not limited to glycine, mannitol, sucrose, L-serine, Tween™ 80 or a combination of one or more of said compounds. The concentration of these compounds depend on the particular compound, but for glycine the concentration may in particular be in the 5 range of 1-200 mM, such as in the range of 5-190 mM, or in the range of 10-180 mM, or in the range of 10-170 mM, or in the range of 20-160 mM, or in the range of 20-150 mM, or in the range of 25-125 mM, or in the range of 5-100 mM, or in the range of 5-90 mM, or in the range of 5-80 mM, or in the range of 5-70 mM, or in the range of 5-60 mM, or in the range of 10-100 mM, or in the range of 10-90 10 mM, or in the range of 10-80 mM, or in the range of 10-70 mM, or in the range of 10-60 mM, or in the range of 12-60 mM, or in the range of 12-55 mM, or in the range of 13.5-54 mM, or in the range of 10-30 mM, such as in the range of 13.5-27 mM, or in the range of 13.5-18 mM, or in the range of 25-55 mM, such as in the range of 27-54 mM, or in the range of 40-55, such as in the range of 40.5-54 15 mM, such as 12.5, 13, 13.5, 14, 14.5, 17, 17.5, 18, 18.5, 19, 25, 26, 27, 28, 29, 30, 39.5, 40, 40.5, 41, 41.5, or 53, 53.5, 53, 54.5 or 55 mM.

The concentration of mannitol may in particular be in the range of 50-1000 mM, such as in the range of 50-900 mM, or in the range of 50-800 mM, or in the range of 50-700 mM, or in the range of 50-600 mM, or in the range of 100-900 mM, or 20 in the range of 100-800 mM, or in the range of 100-700 mM, or in the range of 100-600 mM, or in the range of 100-500 mM, or in the range of 120-525 mM, or in the range of 125-500 mM, or in the range of 100-300 mM, such as in the range of 120-275 mM, or in the range of 120-170 mM, or in the range of 200-600 mM, such as in the range of 225-550 mM, or in the range of 240-510 mM, or in the 25 range of 370-525 mM, such as 120, 125, 130, 160, 165, 166.7, 170, 175, 200, 221, 225, 250, 275, 300, 365, 370, 375, 380, 385, 490, 495, 500, 505 or 510 mM.

The concentration of sucrose may in particular be in the range of 1-200 mM, such as in the range of 5-190 mM, or in the range of 10-180 mM, or in the range of 10-170 mM, or in the range of 20-160 mM, or in the range of 20-150 mM, or in the range of 25-125 mM, or in the range of 5-100 mM, or in the range of 5-90 mM, or in the range of 5-80 mM, or in the range of 5-70 mM, or in the range of 5-60 mM, or in the range of 10-100 mM, or in the range of 10-90 mM, or in the range of 10-80 mM, or in the range of 10-70 mM, or in the range of 10-60 mM, or in the range of 12-60 mM, or in the range of 12-55 mM, or in the range of 13.5-54 mM, or in the range of 10-30 mM, such as in the range of 13.5-27 mM, or in the range of 13.5-18 mM, or in the range of 25-55 mM, such as in the range of 27-54 mM, or in the range of 40-55, such as in the range of 40.5-54 mM, such as 12.5, 13, 13.5, 14, 14.5, 17, 17.5, 18, 18.5, 19, 25, 26, 27, 28, 29, 30, 39.5, 40, 40.5, 41,

41.5, or 53, 53.5, 53, 54.5 or 55 mM. If sucrose is included in a composition which also comprises mannitol the concentration of mannitol may in particular be lowered corresponding to the concentration of sucrose; i.e. the concentration of mannitol and sucrose together may in particular be the same as the concentration 5 of mannitol if this was to be used alone.

The concentration of Tween 80 may in particular be in the range of 0.001-1 w/v%, such as in the range of 0.005-1 w/v%, or in the range of 0.01-1 w/v%, or in the range of 0.001-0.5 w/v%, or in the range of 0.005-0.5 w/v%, or in the range of 10 0.01-0.5 w/v%, or in the range of 0.05-0.4 w/v%, or in the range of 0.05-0.3 w/v%, or in the range of 0.05-0.2 w/v%, or in the range of 0.075-0.4 w/v%, or in the range of 0.075-0.3 w/v%, or in the range of 0.075-0.2 w/v%, or in the range of 0.09-0.2 w/v%, such as 0.075, 0.08, 0.09, 0.1, 0.125, 0.15, 0.175 or 0.2 w/v%.

The composition comprising a polypeptide of interest, wherein the polypeptide in 15 particular may be a PBGD, an aryl sulfatase, a lysosomal alpha-mannosidase or a galactocerebrosidase, may in particular comprise a combination of one or more of the above-mentioned compounds. A suitable example of such a composition may be one which besides the polypeptide of interest comprises  $\text{Na}_2\text{HPO}_4$ , glycine and mannitol. The pH of the composition and the concentration of the different 20 compounds may be as described above. Hence said composition may in one embodiment comprise 0.5-15 mM  $\text{Na}_2\text{HPO}_4$ , 1-200 mM glycine, 50-1000 mM mannitol and a pH in the range of 7.5-8.5. Any combination of the above mentioned concentrations of compounds and pH are encompassed by the present invention. A specific example of a suitable combination of other compounds and 25 pH in the composition comprising a polypeptide of interest is one which comprises 3.67 mM  $\text{Na}_2\text{HPO}_4$ , 27 mM glycine, 250 mM mannitol and has a pH in the range of 7.7 to 7.9.

Other examples of suitable compositions include, but are not limited to any of the following:

- 30 • 1.84 mM  $\text{Na}_2\text{HPO}_4$ , 13.5 mM glycine, 125 mM mannitol and pH in the range of 7.7 to 7.9.
- 2.45 mM  $\text{Na}_2\text{HPO}_4$ , 18 mM glycine, 167 mM mannitol and pH in the range of 7.7 to 7.9.
- 5.51 mM  $\text{Na}_2\text{HPO}_4$ , 40.5 mM glycine, 375 mM mannitol and pH in the range 35 of 7.7 to 7.9.
- 7.34 mM  $\text{Na}_2\text{HPO}_4$ , 54 mM glycine, 500 mM mannitol and pH in the range of 7.7 to 7.9.
- 3.67 mM  $\text{Na}_2\text{HPO}_4$ , 27 mM glycine, 220 mM mannitol, 30 mM sucrose and pH in the range of 7.7 to 7.9.

- 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>, 245 mM mannitol, 32 mM sucrose and pH in the range of 7.7 to 7.9.
- 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>, 27 mM L-serine, 250 mM mannitol and pH in the range of 7.7 to 7.9.
- 5     • 10 mM TRIS-HCl, 27 mM glycine, 250 mM mannitol and pH in the range of 7.7 to 7.9.
- 3.67 mM NaCitrat, 27 mM glycine, 250 mM mannitol and pH in the range of 7.7 to 7.9.
- 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>, 27 mM glycine, 220 mM mannitol, 29 mM sucrose, 10 0.1%(w/v) Tween 80 and pH in the range of 7.7 to 7.9.
- 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>, 27 mM glycine, 220 mM mannitol, 29 mM sucrose, 0.1%(w/v) Tween 80 and pH in the range of 7.7 to 7.9.

The composition comprising a polypeptide of interest may in particular be used for therapeutic applications in mammals. Thus the composition comprising a 15 polypeptide of interest may in particular be isotonic with regard to the tissue of mammals, e.g. it may in particular have an osmolality in the range of 200-400 mOsm/kg, such as in the range of 250-350 mOsm/kg or in the range of 275-325 mOsm/kg or in the range of 295-305 mOsm/kg, such as 295 mOsm/kg or 300 mOsm/kg or 305 mOsm/kg.

20

#### **Method of concentrating a polypeptide of interest**

The method of the present invention comprises the steps of a) centrifugation and/or filtration of a composition comprising a polypeptide of interest and b) concentrating the composition from step a). The inventors of the present 25 invention have found that by centrifugation and/or filtrating a composition comprising a polypeptide of interest prior to concentrating said composition it is possible to obtain a composition comprising a highly concentrated polypeptide of interest without any or with at least only few aggregates of the polypeptide of interest. Furthermore, it is generally an advantage for therapeutic applications of 30 a polypeptide that the amount of polypeptide aggregates is reduced, e.g. as they may increase the risk of eliciting an immune response towards the polypeptide.

For administration of a polypeptide subcutaneously it is an advantage that the polypeptide composition has a high activity in a small volume as only small volumes can be injected subcutaneously.

35 Proteins or polypeptides may in general form aggregates when they are concentrated. Thus it is an advantage that when the method of the present invention is used to concentrate a polypeptide of interest it does not cause a high

rate of polypeptide aggregate formation. As shown in the examples the amount of PBGD aggregates in the composition obtained by the concentration method of the present invention is similar to that of a non-concentrated PBGD composition.

In a particular embodiment step a) of the method is performed prior to step b).

5

**Step a) centrifugation and/or filtration**

The inventors of the present invention have found that prior to concentrating a composition comprising a polypeptide of interest it is an advantage to pre-treat the composition by centrifugation and/or filtration of the composition as by this 10 pre-treatment many or most of the polypeptide aggregates are removed.

When the concentration of the composition in step b) is performed by a method which relies on the use of a filter or membrane, such as ultrafiltration, the presence of aggregates may block the filter or membrane so that small molecules and liquid are not able to cross the filter or membrane. This may decrease the 15 speed by which the composition is concentrated and/or completely block any further concentration.

Hence for this type of concentration the pre-treatment according to step a) is an advantage as removal of the aggregates makes it possible to obtain compositions of a polypeptide of interest which are more concentrated than if said composition 20 were not been pre-treated.

When the concentration of the composition in step b) is performed by a method which is based on the removal of water, such as freeze-drying or evaporation, the pre-treatment in step a) has the advantage that it reduces the amount of aggregates present in the concentrated composition.

25 Step a) may be performed by one of the following three alternatives:

- Centrifugation,
- Filtration, or
- Centrifugation and filtration.

If step a) comprises both centrifugation and filtration it is an advantage to 30 perform the centrifugation prior to the filtration as the inventors of the present invention have found that the centrifugation removes most of large aggregates and the filtration subsequently removes the remaining smaller aggregates.

**Centrifugation**

To be able to remove the aggregates the composition comprising a polypeptide of interest may be centrifuged at a force in the range of 1500 – 3000 g, such as in the range of 1800-2500 g, or in the range of 2000-2300 g.

5 Typically the composition may be centrifuged for 10-60 minutes, such as for 15-50 minutes or for 20-40 minutes.

As the temperature may affect the stability of the polypeptide of interest the centrifugation may be performed at a temperature in the range of 2-20°C, such as from 3-15°C or in the range of 3-10°C, or in the range of 3-8°C, such as at 4°C or 10 5°C or 6°C.

The centrifugation results in that the polypeptide of interest aggregates sediment, i.e. they form a pellet, while the individual polypeptide of interest molecules stays in the solution. So it is the supernatant of the centrifuged composition which is subsequently used in the method of the present invention.

15 **Filtration**

The composition comprising a polypeptide of interest may be filtered through a filter having a pore-size in the range of 0.20-5 µm, such as in the range of 0.2-2.5 µm.

20 Besides the pore-size of the filter also the material of which the filter is made of may affect filtration of polypeptide of interest. Examples of suitable membrane filters include but are not limited to polyethersulfone (PES), cellulose acetate, regenerated cellulose and polyvinylidene flouride (PVDF).

When molecules such as proteins are filtered it is usually the small molecules which are removed thus after filtration the polypeptide of interest may generally 25 be present in the retentate. Hence it is generally the retentate from the filtration which is used in the subsequent steps of the present invention.

**Step b) concentrating**

In principle any method of concentrating the polypeptide of interest composition 30 may be used in step b) of the present invention.

Examples of such suitable methods include but are not limited to ultrafiltration and concentration by removal of water.

Ultrafiltration

Ultrafiltration is a separation method in which hydraulic pressure is used to force molecules and solvent across a membrane comprising pores of a particular size, also known as the cut-off size of value. Only molecules which have a molecular weight smaller than the cut-off value of the membrane are able to cross the membrane while those with a larger molecular weight do not cross the membrane and form the so called retentate. The molecules present in the retentate are thereby concentrated as the solvent flows across the membrane.

In a particular embodiment the concentration of the solution or composition comprising a polypeptide of interest may be performed by Tangential flow filtration (TFF). This method is in particular useful for large-scale concentration, i.e. for concentration of solutions with a volume from one litre to several hundreds of litres. Thus this method is in particular useful for production of concentrated solutions of a polypeptide of interests on an industrial scale.

The TFF technique is based on the use of a particular apparatus which causes the solution which is to be filtrated to flow across a semi-permeable membrane; only molecules which are smaller than the membrane pores will pass through the membrane, forming the filtrate, leaving larger matter to be collected (retentate). With the TFF method two different pressures are applied; one to pump the solution into the system and to circulate it in the system (inlet pressure), and another pressure is applied over the membrane (membrane pressure) to force the small molecules and the solvent across the membrane. The inlet pressure may typically be in the range of 1-3 bar, such as between 1.5-2 bar. The membrane pressure may typically be larger than 1 bar.

The concentrated composition of a polypeptide of interest may be collected as the retentate when TFF is used to concentrate the composition.

Membranes useful for TFF may typically be made of regenerated cellulose or polyethersulfone (PES).

The pore-size of the membrane may typically have a molecular weight cut-off which is smaller than 10.000 Mw, such as in the range of 10-10.000 Mw.

In another embodiment the concentration of the composition comprising a polypeptide of interest may be performed by the use of a centrifugal device. The principle of this method is that the solution is filtrated over a membrane by the

application of a centrifugal force over the membrane. Such membranes are often characterized by a molecular weight (Mw) cut-off, i.e. this is the maximum molecular size of compounds which are able to cross the membrane and compound with a molecular size larger than this will not cross the membrane. The

5 Mw cut-off of the membranes used in the present invention may in particular be smaller than 30.000 Mw, such as between 10-30.000 Mw.

The membrane may in particular be made of polyethersulfone (PES) or regenerated cellulose.

Examples of such suitable commercial filter devices may be Centricon™ Plus-80 or  
10 Centricon™ Plus-15.

The concentration may typically be performed by centrifugation at 2000-4500g, such as between 2500-4000g, or between 2750-3500g, or between 3000-3500g, such as at 3000g or 3100g or 3200g or 3300g or 3400g or 3500g.

Typically the centrifugation may be run for several hours, e.g. for more than one  
15 hour, such as for 1-10 hours.

To minimize any negative effects on the stability of the polypeptide of interest the centrifugation may in particular be performed at a temperature in the range of 2-20°C, such as in the range of 3-15°C or in the range of 3-10°C or in the range of 3-6°C.

20 Concentrating by removal of water

The principle of concentration by removal of water is usually that all, or most, of the water is removed to obtain a solid, and then subsequently diluting or dissolving this solid in a volume of water which is less than what it was previously diluted or dissolved in. However, it may in principle be performed by just

25 removing the necessary amount of water to obtain the desired concentration without subsequently re-diluting or re-dissolving the compound.

Examples of suitable methods of concentrating by removal of water include freeze-drying and evaporation.

Both for freeze-drying and evaporation the three most relevant parameters is the  
30 temperature, pressure and the time.

The method of freeze-drying may be comprise the following three or four steps; a freezing-phase, a primary drying phase and a secondary drying phase and optionally a step of annealing after the freezing phase. Freeze-drying may in

particular be performed as described with regard to freeze-drying included as a further step of the method of the present invention.

### **Further steps**

5 The polypeptide of interest may derive from a natural source, i.e. from cells naturally expressing the polypeptide of interest, or it may in particular be expressed recombinant.

Independent of where the polypeptide of interest derives from it may have been purified before being subjected to a method of the present invention.

10 Such "purification" may in particular include but is not limited to removal of cell debris, removal of other proteins than polypeptide of interest and removal of other components which may be present in the source from which the polypeptide of interest is derived. Thus in a particular embodiment of the present invention the composition comprising a polypeptide of interest comprises less than 5 w/w%,  
 15 or less than 1 w/w% or less 0.5 w/w% or less than 0.1 w/w% or less than 0.05 w/w% or less than 0.01 w/w% other proteins than the polypeptide of interest.

Thus other proteins which are expressed by e.g. a host cell may be removed from the composition comprising a polypeptide of interest before it is used in a method of the present invention.

20 Thus in a particular embodiment the method of the present invention may comprise one or more of following steps prior to step a):  
 i) recombinant expression of a polypeptide of interest  
 ii) purification of polypeptide of interest composition by one or more steps of chromatography  
 25 iii) exchange of the formulation buffer

Recombinant expression of a polypeptide of interest may in particular be performed as described previously with regard to the polypeptide of interest.

If the polypeptide of interest is PBGD examples of suitable types of chromatography include but are not limited to affinity chromatography, Ion 30 Exchange Chromatography (IEC) and chromatography on a hydroxyapatite column. In principle any combination of these chromatography methods may be used. The inventors of the present invention have previously found for PBGD that it is an advantage to perform at least the step of affinity chromatography and if this is combined with any of the other methods of chromatography it is an

advantage to perform the step of affinity chromatography prior to the other chromatography steps (see e.g. WO 03/002731).

For the embodiment where the polypeptide of interest is PBGD examples of commercially available affinity chromatography columns include affinity coupling, 5 group specific affinity, and metal chelate affinity columns.

The product catalogue 2001 of the company Amersham Pharmacia Biotech gives examples of affinity coupling columns such as columns comprising immobilising ligands containing -NH<sub>2</sub> and columns comprising ligands containing primary amino groups.

10 Metal chelate affinity columns are specially preferred for purifying proteins via metal ion complex formation with exposed histidine groups. Example 3 of WO01/07065 describes construction of a recombinant human Porphobilinogen deaminase with a "His-Tag" (rhPBGD-His). In order to purify rhPBGD-His it is preferred to use a metal chelate affinity column, such as a column having a cobalt 15 metal affinity resin.

Examples of other suitable methods of affinity chromatography include but are not limited to columns having porcine heparin as ligand or columns having 1-Amino-4-[[4-[[4-chloro-6-[[3 (or 4)-sulfophenyl]amino]-1,3,5-triazin-2-yl]amino]-3-sulfophenyl]amino]-9,10-dihydro-9,10-dioxo-2-anthracenesulfonic acid, also 20 known as Cibacon Blue 3G, as ligand and using Triazine coupling as the ligand coupling method. A commercially available example of the latter is Blue Sepharose™ 6 Fast Flow (FF) from Amersham Pharmacia Biotech. Accordingly, a preferred embodiment of the invention relates to the process, as described herein, wherein the affinity chromatography column of step (i) is a column using a 25 triazine coupling as ligand coupling method, and more preferably wherein the ligand is Cibacron Blue 3G.

The term "Ion Exchange Chromatography (IEC)" should herein be understood according to the art as a column separating molecules such as proteins on the basis of their net charge at a certain pH by electrostatic binding to a charged 30 group on the column. Ion exchange denotes the absorption of ions of one type onto a column in exchange for others which are lost into solution.

Examples of suitable IEC columns are columns such as a Q Sepharose™ column, a Q SP Sepharose™ column, or a CM Sepharose™ column, it may in particular be a DEAE Sepharose column.

An example of a suitable hydroxyapatite column is a ceramic hydroxyapatite column. Hydroxyapatite ( $\text{Ca}_5(\text{PO}_4)_3\text{OH}_2$ ) is a form of calcium phosphate that can be used for the separation and purification of proteins, enzymes, nucleic acids, viruses, and other macromolecules. Ceramic hydroxyapatite is a spherical,

5 macroporous form of hydroxyapatite. CHT Type I (Bio-Rad) is an example of a suitable commercially available ceramic hydroxyapatite chromatography column.

In one embodiment the method of the present invention may comprise the following steps prior to step a):

- 10 i) recombinant expression of PBGD
- ii) subjecting the PBGD composition from step i) to affinity chromatography
- iii) subjecting the PBGD composition of step ii) to ion exchange chromatography

In a further embodiment the method of the present invention may comprise the following steps prior to step a):

- 15 i) recombinant expression of PBGD
- ii) subjecting the PBGD composition from step i) to affinity chromatography
- iii) subjecting the PBGD composition from step ii) to ion exchange chromatography
- 20 iv) subjecting the PBGD composition from step iii) to a hydroxyapatite column

Both of these methods may optionally include a further step of dilution of diafiltration of the PBGD composition obtained from step ii). Thus said step should 25 be after step ii) and before iii), i.e. a step iia). Step iia) has the purpose of reducing the concentration of salts to suitable conductivity, e.g. < 10 mS/cm. This may in particular be relevant if DEAE Sepharose is used as resin in the ion exchange chromatography step, i.e. step iii), as this may facilitate binding of the captured PBGD to the DEAE Sepharose resin. Dilution may be obtained by addition 30 of purified water directly or by ultrafiltration against purified water.

The recombinant expression of PBGD, step i) may be performed by any of the methods described above.

Examples of suitable affinity chromatography columns in step ii) may be any of the above mentioned.

35 Examples of suitable methods of performing ion exchange chromatography in step iii) may be any of the above mentioned.

Examples of suitable hydroxyapatite chromatography columns in step iv) may be any of the above mentioned.

In a particular embodiment the affinity chromatography column may be a column using a triazine coupling as ligand coupling method, and in particular such a

5 method wherein the ligand is Cibacon Blue 3G. This may in particular be a Blue Sepharose 6 Fast Flow column, and the ion exchange chromatography column may be DEAE Sepharose column, and in the embodiment wherein the method also comprises a step iv) this column may in particular be a ceramic hydroxyapatite column.

10 The method of the present invention may also comprise further steps after step b) of the method. Such steps include but are not limited to one or more of the following:

- freeze-drying the composition comprising a concentrated polypeptide of interest,

15     • changing the buffer of the composition comprising a concentrated polypeptide of interest,

- sterile filtration of the composition comprising a concentrated polypeptide of interest
- evaporation

20 Different freeze-driers, volume of solutions to be freeze-dried and other parameters may be used in the method of the present invention. An example of a suitable freeze-dryer includes but is not limited to a Lyostar (FTM-systems) freeze-drier as used the examples of the present invention, where the solutions comprising a concentrated polypeptide of interest, i.e. in this case PBGD, were

25 filled in 2 and 6 ml injection glass vials (type 1) and stoppered with rubber stoppers (chlorobutyl). The freeze-drying may be performed by the following three steps;

- i) freezing,
- ii) primary drying, and

30     iii) secondary drying .

Step i) freezing may in particular be performed by first loading a sample in ambient temperature and cooling it to 0°C and keeping it at 0°C for 30 minutes, before lowering the temperature by 1°C per minute to -40°C and keeping it at -40°C for 30 minutes.

35 Step ii) primary drying may in particular be performed by drawing the vacuum pressure 126 mTorr, raising the temperature by 1°C per minute to 0°C and keeping the sample at 0°C for 360 minutes

Step iii) secondary drying may in particular be performed by drawing the full vacuum simultaneously with raising the temperature by 0.5°C per minute to +30°C and keeping the sample at +30°C for 360 minutes.

After the secondary drying the sample may further be closed under vacuum or

5 closed after filling with nitrogen.

An example of a suitable freeze-drying method includes the one described in the examples of the present invention.

The freeze-drying may in further embodiment comprise an annealing step prior to the primary drying phase. The inventors of the present invention have found that

10 inclusion of an annealing step in the freeze-drying method improves the visual appearance, as visualised by fewer cracks, and/or results in a shorter reconstitution time of the freeze-dried product compared to when the same method of freeze-drying is used but without the annealing step. It is an advantage that the time for reconstitution of a freeze-dried product is reduced, especially if it

15 is to be used as a pharmaceutical which is administered as a solution. An improved visual appearance is usually also regarded as an advantage for most products.

Thus the freeze-drying may comprise the following steps:

- 20 i) freezing
- ii) annealing
- iii) primary drying
- iv) secondary drying.

The freezing, primary drying and secondary drying steps may in particular be performed as described above. The annealing step, i.e. step ii) may in particular

25 be performed by after 30 minutes of freezing, raising the temperature at e.g. a rate of 2°C per minute to -10°C or -20°C and keeping this temperature for 120 or 420 minutes and then lowering the temperature e.g. a rate of 2°C per minute to -40°C at which temperature the sample may be kept at 60-90 minutes before start of the step of primary drying.

30 Changing the buffer of the composition comprising a concentrated polypeptide of interest may in particular be performed by a) diluting, e.g. 5-15 times, the composition comprising a concentrated polypeptide of interest in a buffer or formulation, b) concentrating the diluted composition again and performing the steps a) and b) a sufficient number of times so that amount of the excipients in

35 the buffer or formulation present in the composition before these steps constitute

less than e.g 5 v/v% or less than 1 v/v% of excipients in the the buffer or formulation present in said composition after said steps were performed.

In particular the composition comprising a polypeptide of interest obtained from step b) of the present invention may in particular further comprise a step of sterile 5 filtration of said composition and/or a step of freeze-drying the composition.

Sterile filtration is generally performed by filtration of the composition through a filter with a pore-size of 0.22 µm or 0.20 µm. Freeze-drying may in particular be performed as described above.

The present invention also relates to a freeze-dried composition obtained by a 10 method of the present invention.

### **Subcutaneous injection**

The present invention also relates to the use of a composition comprising in the range of 50-300 mg/ml polypeptide of interest for the manufacture of a 15 medicament for subcutaneous injection into a mammal.

The polypeptide of interest may be any polypeptide of interest according to the present invention, including but not limited to PBGD, aryl sulfatase A, lysosomal alpha-mannosidase and galactocerebrosidase.

The term subcutaneous is often shortened to s.c. and the two terms may be used 20 interchangeably in the context of the present invention.

When injection is performed subcutaneously it is usually not possible to inject more than 1.5 mL due to physiologically restraints.

As the patient usually needs a certain amount of the particular polypeptide of interest there is a correlation between the volume of the composition comprising a 25 polypeptide of interest which needs to be administered to the patient and of the concentration of polypeptide of interest in said composition.

It is therefore an advantage of the present invention that the composition comprising a polypeptide of interest comprises a high concentration of the polypeptide of interest and that this high concentration of the polypeptide of 30 interest can be obtained without the formation of large amounts of polypeptide aggregates. The use of such concentrated polypeptide of interest compositions makes it possible to inject a smaller volume of said composition and at the same time ensure that the patient receives an adequate amount of the polypeptide of

interest; thus making it easier to administer the polypeptide of interest subcutaneously.

The above-mentioned composition comprising a polypeptide of interest may in particular comprise between 75-250 mg/ml, such as between 75-200 mg/ml or 5 between 75-150 mg/ml or between 100-150 mg/ml or between 100-125 mg/ml or between 125-150 mg/ml of polypeptide of interest.

As described above the volume of composition comprising a polypeptide of interest which it is necessary to inject into the patient to ensure that the patient receives an adequate amount of the polypeptide of interest correlates with the 10 concentration of the polypeptide of interest in said composition.

Thus the volume of such a composition will generally be adjusted according to the concentration of the polypeptide of interest in the composition. However, the volume may generally be in the range of 0.1-1.5 ml, such as in the range of 0.1-1.5 ml or in the range of 0.5-1.5 ml or in the range of 0.5-1.5 ml or in the range 15 of 0.75-1.5 ml or in the range of 0.75-1.5 ml or in the range of 1-1.5 ml or in the range of 1-1.5 ml.

The amount of polypeptide of interest which it is relevant to administer to a patient generally depends on the weight of the individual and the particular polypeptide of interest.

20 In one embodiment the present invention relates to a method of treating a mammal for Acute Intermittent Porphyria comprising subcutaneous injection of a composition of 50-300 mg/ml PBGD.

Administration of PBGD may in particular be useful for the treatment of Acute Intermittent Porphyria. However, it is contemplated that administration of PBGD 25 also may be useful for the treatment of other porphyrias, such as Hereditary coproporphyria or Variegata porphyria. Porphyria is a term used to collectively describe a number of diseases caused by different deficiencies in the heme biosynthetic pathway. Hence it is contemplated that administration of PBGD, e.g. in combination with other therapeutics, to a patient suffering from any type of 30 porphyria may help to increase the overall turnover of the different intermediates in the pathway. For example Meissner PN et al., 1986, European Journal of Clinical Investigation, vol. 16, 257-261; Hift RJ et al., 1997, S. Afr. Med. J., vol. 87, 718-27 and Meissner P et al., 1993, J. Clin. Invest., vol. 91, 1436-44 describe 35 accumulation of ALA and PBG in Hereditary coproporphyria and Variegata porphyria. In these diseases the accumulation of ALA and PBG results from enzymatic defects that are located four and five steps downstream from the

conversion of ALA to PBG, respectively. In the two most recent papers it is described how the porphyrinogen which accumulates in patients with Variegata porphyria is capable of inhibiting PBG-deaminase.

In a further embodiment the present invention relates to a method of treating a 5 mammal for metachromatic leukodystrophy comprising subcutaneous injection of a composition of 50-300 mg/ml aryl sulfatase A.

Metachromatic leukodystrophy (MLD) is caused by an autosomal recessive genetic defect in the lysosomal enzyme Arylsulfatase A (ASA), resulting in a progressive breakdown of membranes of the myelin sheath (demyelination) and accumulation 10 of galactosyl sulphatide (cerebroside sulphate) in the white matter of both the central nervous system (CNS) and the peripheral nervous system. In histologic preparations, galactosyl sulphatide forms spherical granular masses that stain metachromatically. Galactosyl sulphatide also accumulates within the kidney, gallbladder, and certain other visceral organs and is excreted in excessive 15 amounts in the urine.

Galactosyl sulphatide is normally metabolised by the hydrolysis of 3-O-sulphate linkage to form galactocerebroside through the combined action of the lysosomal enzyme arylsulfatase A (EC 3.1.6.8) (Austin et al. Biochem J. 1964, 93, 15C-17C) and a sphingolipid activator protein called saposin B. A profound deficiency of 20 arylsulfatase A occurs in all tissues from patients with the late infantile, juvenile, and adult forms of MLD (see below). In the following, the arylsulfatase A protein will be termed "ASA". A profound deficiency of ASA occurs in all tissues from patients with MLD.

In yet another embodiment the present invention relates to a method of treating a 25 mammal for the lysosomal storage disorder alpha-mannosidosis comprising subcutaneous injection of a composition of 50-300 mg/ml lysosomal alpha-mannosidase.

Alpha-mannosidosis is a recessive, autosomal disease that occurs world wide with a frequency of between 1/1.000.000 and 1/500.000. Mannosidosis is found in all 30 ethnic groups in Europe, America, Africa and also Asia. It is detected in all countries with a good diagnostic service for lysosomal storage disorders, at a similar frequency. They are born apparently healthy; however the symptoms of the diseases are progressive. Alpha-mannosidosis displays clinical heterogeneity, ranging from very serious to very mild forms. Typical clinical symptoms are: 35 mental retardation, skeletal changes, impaired immune system resulting in recurrent infections, hearing impairment and often the disease is associated with a typical facial characteristics such as a coarse face, a prominent forehead, a

flattened nasal bridge, a small nose, and a broad mouth. In the most severe cases (mannosidosis type I) the children suffer from hepatosplenomegaly, and they die during the first years of life. Possibly this early death is caused by severe infections due to the immunodeficiency caused by the disease. In milder cases 5 (mannosidosis type 2) the patients usually reach adult age. The skeletal weaknesses of the patients result in the needs of wheeling chairs at age 20 to 40. The disease causes a diffuse dysfunction of the brain often resulting in weak mental performances that excludes anything but the most basic skills of simple reading and writing. These problems associated with hearing inabilities and other 10 clinical manifestations preclude the patient from an independent life, the consequence being that life long caretaking is needed.

In yet another embodiment the present invention relates to a method of treating a mammal for Krabbe disease comprising subcutaneous injection of a composition of 50-300 mg/ml galactosylcerebrosidase.

15 In humans a deficiency in the GALC enzyme results in an autosomal inherited genetic Lysosomal Storage disease known as Krabbe disease or Globoid Cell Leukodystrophy. The enzyme is generally expressed in the testis, kidneys, placenta, liver and brain of human beings and a deficiency in the GALC enzyme generally results in a disorder in the myelin metabolism and in the central and 20 peripheral nervous systems (the CNS and PNS, respectively).

Krabbe disease has been observed in humans of any age, nationality and sex.

It should be noted that embodiments and features described in the context of one of the aspects of the present invention also apply to the other aspects of the invention. In particular, all of the embodiments described for the composition 25 comprising a polypeptide of interest, such as the presence of further compounds, buffers and pH also apply to the composition comprising a polypeptide of interest used in the present applications.

When an object according to the present invention or one of its features or 30 characteristics is referred to in singular this also refers to the object or its features or characteristics in plural. As an example, when referring to "a polypeptide" it is to be understood as referring to one or more polypeptides.

Throughout the present specification the word "comprise", or variations such as 35 "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the

exclusion of any other element, integer or step, or group of elements, integers or steps.

The invention will now be described in further details in the following non-limiting

5 Experimental sections.

## EXPERIMENTAL

### Materials

#### rhPBGD

10 The rhPBGD used in the following experiments were obtained according to process 2 in example 1 of WO 03/002731, where process 2 is the process which includes step IV, i.e. the ceramic hydroxyapatite chromatography step.

#### Formulation buffer

The recombinant and purified rhPBGD was present in the following aqueous

15 formulation buffer:

3.67 mM Na<sub>2</sub>HPO<sub>4</sub>  
 27 mM Glycine  
 250 mM Mannitol  
 and a pH of 7.9

20 The formulation buffer was then sterile-filtered through a 0.22 µm filter.

### Methods

#### Freeze-drying

The freeze-drying of the purified rhPBGD solutions were performed in a Lyostar (FTM-systems) freeze-drier according to the following schedule:

Freezing phase	0°C	30 min	760 Torr
	0°C to -40°C	1°C/min	760 Torr
	-40°C	30 min	760 Torr
Primary drying	-40°C to 0°C	1°C/min	169 mTorr
	0°C	240 min	169 mTorr

Secondary drying	0°C to 30°C	10°C/60 min, 180 min	20 mTorr
	30°C	720 min	20 mTorr

#### Visual observation (Clarity and colour)

The liquid was visually studied with respect to colour, clarity and precipitates according to the scheme below.

5 Colour: 1: No colour; 2: Slightly yellow; 3: Yellow

Clarity: 1: Clear; 2: Slightly turbid; 3: Turbid

Other remarks: Other observations from the operator were in some instances included here (e.g. precipitates, undissolved material etc)

#### pH-measurement

10 The pH-meter (Metrohm™ 691 pH Meter) and electrode (combined LL pH electrode) were calibrated with 3 standard reference solutions (Merck) in the range 4.00 to 9.00. The liquid was finally analysed.

#### Protein concentration

15 Protein concentration in extract, in-process samples, bulk drug substance and final product was determined by a method that utilizes principles of the reduction of Cu<sup>2+</sup> to Cu<sup>+</sup> by protein in an alkaline medium (the Biuret reaction). The Cu<sup>+</sup> ions were then reacted with a reagent containing bicinchoninic acid resulting in a highly sensitive and selective colorimetric detection.

#### Purity

20 Recombinant human Porphobilinogen Deaminase (rhPBGD) and rhPBGD variants were separated according to their ability to adsorb and desorb to silica based stationary media depending on the percentage of organic modifier (acetonitrile) in the mobile phase.

#### rhPBGD activity

25 Porphobilinogen deaminase (PBGD) catalyzes the addition of 4 molecules of porphobilinogen (PBG) to form a linear tetramer, preuroporphyrinogen, which is released from the enzyme and in vivo circularized to uroporphyrinogen III by the action of Uroporphyrinogen III synthase. Preuroporphyrinogen can be chemically oxidized with benzoquinone to form uroporphyrin, which absorbs light at 405 nm.

The analyses were performed on one single vial on each test occasion. For the determination of rhPBGD activity and protein concentration the tests were performed in duplicate and triplicate respectively, for each vial.

Osmolality

5 One vial of freeze-dried rhPBGD was resuspended in 1.00 ml MilliQ-water. The vial of frozen aqueous solution of rhPBGD was thawed. The osmometer (Vapro osmometer) was calibrated with 3 standard solutions in the range 100-1000 mOsm/kg (100, 290, 1000 mOsm/kg). The liquid was then analyzed.

**10 Example 1**

Concentrating with centrifugal filter devices

Frozen PBGD-bulk solution (7 mg/mL rhPBGD, 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>, 27 mM glycine, 250 mM Mannitol, pH 7.9) was thawed in a water-bath at 20 °C, centrifuged at 3200g for 10 min and thereafter sterile-filtrated by 0.20 µm-PES filters (Nalgene 15 Polyethersulfone filters). The PBGD-bulk solution was concentrated to 100 mg/ml by running the Centrifugal Filter Devices Centricon Plus-80 (Mw cut-off 30000) and Centricon Plus-15 (Mw cut-off 30000) at 3200 g for several hours. The concentrated solution, i.e. the retentate, was sterile-filtrated by 0.22 µm-filters (Millex GV) and finally a part of this solution was diluted with sterile formulation 20 buffer to get 50 mg/ml. The 5 mg/ml-solution was prepared by directly diluting the recombinant and purified hPBGD with sterile formulation buffer.

The 5 mg/mL, 50 mg/mL and 100 mg/mL rhPBGD were then freeze-dried as described above. Several vials of each the above-mentioned freeze-dried rhPBGD 25 solutions with 5, 50 and 100 mg/mL rhPBGD and of the aqueous 5 mg/mL rhPBGD solution were stored at 40°C ± 2°C, 75% ± 5% relative humidity (RH). The vials were stored protected from light in a well sealed secondary package (paper box).

At the indicated time points (i.e. time of storage) a vial of each freeze-dried samples were resuspended in 1.00 mL Millipore water.

30 Each of the resuspended vials and the aqueous vial of rhPBGD were then visually observed with regard to colour, clarity and precipitates, and the pH, protein concentration, purity and rhPBGD activity were measured as described above.

The results are given in the following tables 1-4:

Table 1: Freeze-dried product, 5 mg/mL

Time-point (month)	Activity (U/ml)	Concentration (mg/ML)	Specific activity (U/mg)	Purity (%)	Visual observation
0	93.2	4.3	21.5	99.6	Colour: 1, clarity: 1
0.5	81.0	5.2	15.6	ND	Colour: 1, clarity: 1
1	76.6	5.9	13.1	99.9	Colour: 1, clarity: 1
1.5	87.0	5.5	15.9	99.7	Colour: 1, clarity: 1
2	53.3	4.7	11.4	99.6	Colour: 1, clarity: 1
3	50.8	4.8	10.7	99.6	Colour: 1, clarity: 1
6	34.3	5.3	6.5	99.6	Colour: 1, clarity: 1

5 Table 2; freeze-dried product; 50 mg/ml

Time-point (month)	Activity (U/ml)	Concentration (mg/ML)	Specific activity (U/mg)	Purity (%)	Visual observation
0	888	41.4	21.5	99.1	Colour: 2, clarity: 1
0.5	842	50.6	16.6	ND	Colour: 2, clarity: 1
1	746	50.6	14.8	100	Colour: 2, clarity: 1
2	640	52.9	12.1	100	Colour: 2, clarity: 1
3	634	49.0	12.9	100	Colour: 2, clarity: 1
6	422	43.0	9.8	100	Colour: 2, clarity: 1

Table 3: Freeze-dried product; 100 mg/ml

Time-point (month)	Activity (U/ml)	Concentration (mg/ML)	Specific activity (U/mg)	Purity (%)	Visual observation
0	1944	83.7	23.2	99.1	Colour: 3, clarity: 1
1	1470	98.7	14.9	100	Colour: 3, clarity: 1
2	1282	94.8	13.5	100	Colour: 3, clarity: 1
3	1253	82.6	15.2	100	Colour: 3, clarity: 1
6	739	75.5	9.8	100	Colour: 3, clarity: 1

Table 4: Aqueous product; 5 mg/ml

Time-point (month)	Activity (U/ml)	Concentration (mg/ML)	Specific activity (U/mg)	Purity (%)	Visual observation
0	95.6	4.0	23.7	99.1	Colour: 1, clarity: 1
0.5	48.1	5.4	8.9	ND	Colour: 1, clarity: 1
1	28.6	5.9	4.8	96.1	Colour: 1, clarity: 1
1.5	12.3	5.6	2.2	91.4	Colour: 1, clarity: 1
2	4.5	4.4	1.0	90.7	Colour: 1, clarity: 1
3	7.1	3.1	2.3	87.3	Colour: 2, clarity: 2
6	4.4	2.1	2.1	58.1	Colour: 2, clarity: 2

**Example 2**Concentrating a rhPBGD composition by centrifugal filter devices

Frozen PBGD-bulk solution (7 mg/mL rhPBGD, 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>, 27 mM glycine, 250 mM Mannitol, pH 7.9) was thawed in a water-bath at 20 °C, centrifuged at 3200g for 10 min and thereafter sterile-filtrated by 0.20 µm-PES filters (Nalgene Polyethersulfone filters). The PBGD-bulk solution was concentrated to 100 mg/ml

5 by running the Centrifugal Filter Devices Centricon Plus-80 (Mw cut-off 30000) and Centricon Plus-15 (Mw cut-off 30000) at 3200 g for several hours. The concentrated solution, i.e. the retentate,

10 was sterile-filtered by 0.22  $\mu$ m-filters (Millex GV) and diluted with sterile filtered formulation buffer (see above) to get solutions of lower concentrations. A fraction in volume of each concentration was freeze-dried as described above.

The different concentrations of freeze-dried rhPBGD and aqueous solution of rhPBGD were stored at  $5^{\circ}\text{C} \pm 3^{\circ}\text{C}$  or at  $-20^{\circ}\text{C} \pm 5^{\circ}\text{C}$  (ambient relative humidity (RH)). All vials were stored protected from light in a well-sealed secondary package (paper box).

15 At the indicated time points (i.e. time of storage) a vial of each freeze-dried samples were resuspended in 1.00 mL Millipore water and then tested together with the aqueous solution of rhPBGD by visually observing the colour, clarity and precipitates, and by measuring pH, protein concentration, purity, osmolality and rhPBGD activity.

20 The results are given in the following tables 5-19:

Table 5: Aqueous product; 11 mg/ml; Storage temp.: +5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	PH	Osmolality (mOsm/kg)	Visual observation
0	10.9	255.0	23.4	100.0	7.80	290	Colour: 2 Clarity: 1 Clear None/few
1	9.5	216.8	22.8	100.0	7.81	305	Colour: 2 Clarity: 1 Clear None/few

2	10.9	230.2	21.1	98.0	7.80	300	Colour: 2 Clarity:1 Clear None/few
3	11.2	226.6	20.2	100.0	7.76	290	Colour: 2 Clarity:1 Clear Few
6	14.7	271.1	18.4	100.0	7.77	300	Colour:2 Clarity:1 Clear Several

Table 6: Aqueous product: 11 mg/ml; Storage temp: -20°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	PH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	10.4	236.1	22.6	100	7.80	290	Colour: 2 Clarity:1 Clear None
1	11.7	270.3	23.1	100	7.81	302	Colour: 2 Clarity:1 Clear None
2	ND	ND	ND	ND	ND	ND	ND
3	12.4	247.7	20.0	100	7.77	288	Colour: 2 Clarity:1 Clear None
6	13.4	291.5	21.8	100	7.77	301	Colour: 2 Clarity:1 Clear None

Table 7: Freeze-dried product, 11 mg/ml; Storage temp.: +5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation
							Colour 1-3; Clarity 1-3; Solution; Aggregates
0	10.9	230.0	21.2	100.0	7.80	290	Colour: 2 Clarity: 1 Clear None
1	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND
3	13.3	269.3	20.2	100.0	7.74	282	Colour: 2 Clarity: 1 Clear None
6	14.7	237.9	16.2	100.0	7.76	290	Colour: 2 Clarity: 1 Clear None

5

Table 8: Aqueous product, 17 mg/ml; Storage temp.: +5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation
0	18.0	471.0	26.1	100.0	7.80	298	Colour: 2 Clarity: 1 Clear None/few
1	17.5	360.4	20.6	100.0	7.81	311	Colour: 2 Clarity: 1 Clear

Table 9: Aqueous product, 17 mg/ml; Storage temp.: -20°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	PH	Osmolality (mOsm/kg)	Visual observation
0	17.9	411.6	23.0	100.0	7.80	298	Colour: 2 Clarity: 1 Clear None
1	17.4	439.5	25.3	100.0	7.80	310	Colour: 2 Clarity: 1 Clear None
2	ND	ND	ND	ND	ND	ND	ND
3	16.4	389.4	23.7	100.0	7.77	292	Colour: 2 Clarity: 1 Clear None
6	18.0	373.8	20.8	100.0	7.76	305	Colour: 2 Clarity: 1 Clear

Table 10: Freeze-dried product, 17 mg/ml; Storage temp.: 5°C

5

Table 11: Aqueous product; 36 mg/ml; Storage temp.: +5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation
0	36.0	844.4	23.4	100.0	7.81	305	Colour: 2 Clarity: 1 Clear None/few
1	35.5	778.1	21.9	100.0	7.82	314	Colour: 2 Clarity: 1

							Clear
							None/few
2	35.4	798.5	22.6	100.0	7.81	310	Colour: 2
							Clarity: 1
							Clear
							None/few
3	28.9	687.9	23.8	100.0	7.77	303	Colour: 2
							Clarity: 1
							Clear
							Few
6	37.2	537.3	14.4	100.0	7.77	312	Colour: 2
							Clarity: 1
							Clear
							Several

Table 12: Aqueous product, 36 mg/ml;

Storage temp.: -20°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	34.0	853.4	25.1	100.0	7.81	305	Colour: 2 Clarity: 1 Clear None
1	38.0	853.6	22.5	100.0	7.83	321	Colour: 2 Clarity: 1 Clear None
2	ND	ND	ND	ND	ND	ND	ND
3	31.6	776.3	24.6	100.0	7.76	299	Colour: 2 Clarity: 1 Clear None
6	30.6	543.8	17.8	100.0	7.75	311	Colour: 2 Clarity: 1 Clear

							None
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Table 13: Freeze-dried product, 36 mg/ml; Storage temp.: 5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	29.5	657.0	22.3	100.0	7.81	305	Colour: 2 Clarity: 1 Clear None
1	ND	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND	ND
3	28.7	747.6	26.0	100.0	7.75	290	Colour: 2 Clarity: 1 Clear None
6	29.8	579.3	19.4	100.0	7.76	300	Colour: 2 Clarity: 1 Clear None

5

Table 14: Aqueous product, 50 mg/ml; Storage temp.: 5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	46.2	780.9	16.9	96.3	7.59	317	Colour: 3 Clarity: 1 Slightly opalescent None
1	47.9	915	19.1	90	7.58	305	Colour: 3

							Clarity: 1
							Slightly opalescent
							None
2	47.2	898.3	19.0	100	7.60	318	Colour: 3
							Clarity: 1
							Slightly opalescent
							None
3	60.8	1102.6	18.1	100	7.72	314	Colour: 3
							Clarity: 1
							Clear
							None
6	62.5	902.8	14.4	100	7.60	331	Colour: 3
							Clarity: 2
							Clear
							None
9	41.7	618.5	14.8	100	7.60	336	Colour: 3
							Clarity: 2
							Clear
							None
12	50.2	540.8	10.8	97.5	7.60	329	Colour: 3
							Clarity: 2
							Clear
							None

Table 15: Aqueous product, 50 mg/ml; Storage temp.: -20°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	PH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	46.2	780.9	16.9	96.3	7.59	317	Colour: 3 Clarity: 1 Slightly opalescent None

1	47.2	899.1	19.0	93.7	7.58	313	Colour: 3 Clarity: 1 Slightly opalescent None
2	53	1222.7	23.1	100.0	7.60	315	Colour: 3 Clarity: 1 Slightly opalescent None
3	61.2	1336.2	21.8	100.0	7.75	320	Colour: 3 Clarity: 1 Slightly opalescent None
6	52.2	1001.3	19.2	100.0	7.60	321	Colour: 3 Clarity: 1 Slightly opalescent None
12	50.4	887.9	17.6	100.0	7.60	320	Colour: 3 Clarity: 1 Slightly opalescent None

Table 16: Freeze-dried product, 50 mg/ml; Storage temp.: 5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Cake/solution Aggregates
0	42.7	759.4	17.8	100.0	7.58	292	Colour: 3 Clarity: 1

								Cake: yellow, some cracks Solution: Clear None
1	42.6	840.4	19.7	63.1	7.58	293		Colour: 3 Clarity: 1
								Cake: yellow, some cracks Solution: Clear None
2	42.1	937.0	22.3	100.0	7.60	292		Colour: 3 Clarity: 1
								Cake: yellow, some cracks Solution: Clear None
3	47.4	1014.7	21.4	100.0	7.75	291		Colour: 3 Clarity: 1
								Cake: yellow, some cracks Solution: Clear None
6	49.0	876.5	17.9	100.0	7.60	304		Colour: 3 Clarity: 1
								Cake: yellow, some cracks Solution: Clear None
12	51.3	945.0	18.4	100.0	7.60	308		Colour: 3 Clarity: 1
								Cake: yellow, some cracks Solution: Clear None

Table 17: Aqueous product, 100 mg/ml; Storage temp.: 5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	PH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	81.8	1705.7	20.9	99.9	7.60	350	Colour: 3 Clarity: 1 Slightly opalescent None
1	85.9	1942.4	22.6	96.9	7.55	352	Colour: 3 Clarity: 1 Slightly opalescent None
2	95.7	1690.8	17.7	96.9	7.65	357	Colour: 3 Clarity: 1 Slightly opalescent None
3	104.3	1671.2	16.0	100.0	7.65	350	Colour: 3 Clarity: 1 Slightly opalescent None
6	96.0	1642.6	17.1	100.0	7.62	360	Colour: 3 Clarity: 1 Slightly opalescent None
9	102.8	1270.8	12.4	100.0	7.63	352	Colour: 3 Clarity: 2 Slightly opalescent None

11	86.2	1140.2	13.2	100.0	7.60	353	Colour: 3 Clarity: 2 Slightly opalescent None
12	113.9	1550.6	13.6	100.0	7.58	350	Colour: 3 Clarity: 2 Slightly opalescent None
15	114.7	1160.6	10.1	98.3	7.61	350	Colour: 3 Clarity: 2 Slightly opalescent None
18	86.2	907.4	10.5	100.0	7.67	340	Colour: 3 Clarity: 2 Slightly opalescent None

Table 18: Aqueous product, 100 mg/ml; Storage temp.: -20°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation Colour 1-3 Clarity 1-3 Solution Aggregates
0	81.8	1705.7	20.9	99.9	7.60	316	Colour: 3 Clarity: 1 Slightly opalescent None
1	89.3	2108.8	23.6	100.0	7.56	350	Colour: 3 Clarity: 1 Slightly opalescent None

2	112.0	2066.5	18.5	100.0	7.65	353	Colour: 3 Clarity: 1 Slightly opalescent None
3	100.2	2172.4	21.7	96.7	7.65	352	Colour: 3 Clarity: 1 Clear None
6	87.5	2672.3	30.6	100.0	7.62	352	Colour: 3 Clarity: 1 Clear None
9	97.1	2040.3	21.0	100.0	7.62	353	Colour: 3 Clarity: 1 Clear None
11	104.6	2234.0	21.4	100.0	7.60	353	Colour: 3 Clarity: 1 Clear None
12	94.5	1608.8	17.0	100.0	7.57	350	Colour: 3 Clarity: 1 Slightly opalescent None
15	118.0	2015.9	17.1	100.0	7.62	351	Colour: 3 Clarity: 1 Slightly opalescent None
18	90.6	1736.4	19.2	100.0	7.69	338	Colour: 3 Clarity: 1 Slightly opalescent None

Table 19: Freeze-dried product, 100 mg/ml; Storage temp.: 5°C

Time-point (month)	Protein conc. (mg/ml)	Activity (U/ml)	Specific activity (U/mg)	Purity (%)	pH	Osmolality (mOsm/kg)	Visual observation
0	76.0	1638.3	21.5	100.0	7.60	316	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear None
1	71.6	1747.6	24.4	100.0	7.55	318	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear None
2	81.6	1769.9	21.7	100.0	7.63	313	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear None
3	84.1	1616.6	19.2	98.2	7.65	320	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear None
6	96.7	2197.6	22.7	100.0	7.60	324	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear

							None
9	ND	ND	ND	ND	ND	ND	ND
12	96.0	1978.4	20.6	100.0	7.57	322	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear None
15	ND	ND	ND	ND	ND	ND	ND
18	80.6	1602.6	19.9	100.0	7.75	310	Colour: 3 Clarity: 1 Cake: Yellow, some cracks Solution: Clear None

### Example 3

#### Concentrating a rhPBGD composition by tangential flow filtration (TFF)

5 The bulk solution of rhPBGD was then thawed for a minimum of three days at 5°C and in darkness.

The thawed solution was then centrifuged with 200 mL conical centrifuge tubes for approximately 10 minutes at 2200g.

10 The solution was then filtered through a series of filters with the following pore-sizes: 5.0 µm; 0.65 µm; 0.45 µm and 0.20 µm before it was concentrated by tangential flow filtration (TFF).

15 The concentration by TFF was performed with a Millipore Labscale TFF System and Millipore Pellicon® XL Filter with a pump inlet pressure of approximately 20-25 psi and a pressure over the Pellicon® XL Filter of approximately 4-6 psi. The rhPBGD was protected from light during the procedure by covering the sample container of the TFF System by sheets of aluminium foil.

The concentrated rhPBGD solution obtained from the TFF procedure was then buffer-changed against a formulation buffer containing 3.67 mM Na<sub>2</sub>HPO<sub>4</sub> x 2H<sub>2</sub>O,

27 mM glycine and 220 mM Mannitol prepared in sterile water. This was performed by continuously adding said buffer to the TFF-system and pressing it across the membrane until said buffer has replaced the previous buffer.

The concentrated and buffer-changed rhPBGD solution was then sterile filtered by 5 passing it through a filter with a pore-size of 0.22 µm. This sterile filtration was performed twice with a new filter each time.

The sterile concentrated rhPBGD solution was then placed in vials before it was freeze-dried as described in the method section.

#### 10 Example 4

##### The effect of different modes of freeze-drying and/or the amount of excipients on the reconstitution time

PBGD was concentrated as described in example 3 and after the exchange of the buffer was the concentration of PBGD determined.

15 The concentrated PBGD solution was then freeze-dried in a Lyostar (FTM-systems) freeze-dryer. The solutions were filled in 2 and 6 ml injection glass vials (type 1) and stoppered with rubber stoppers (chlorobutyl).

##### *Original freeze-drying cycle:*

The samples were loaded in ambient temperature and the shelves were cooled 20 down to 0°C for 30 minutes. The temperature were lowered to -40°C (1°C per minute) and held there for 30 minutes and then the vacuum pressure was drawn to 126 mTorr and the primary drying began by raising the temperature to 0°C (1°C per minute). After 360 minutes of primary drying the temperature was raised to +30°C (0.5 °C per minute) and full vacuum was drawn simultaneously 25 (start of secondary drying). The temperature was held at +30°C for 360 minutes and the vials were then stoppered under vacuum.

##### *Freeze-drying with inclusion of an annealing step:*

After 30 minutes at -40°C the temperature was raised with a rate of 2°C per minute to -10°C or -20°C at which temperature they were kept for 120 or 420 30 minutes before the temperature was lowered again with 2°C per minute to -40°C were the samples were kept for 60-90 minutes before start of primary drying.

The results are shown in Table 20 where the short terms used with regard to the excipients and the freeze-drying cycle mean the following:

1x amount of excipients refers to that the PBGD solution comprises 3.67 mM Na<sub>2</sub>HPO<sub>4</sub> x 2H<sub>2</sub>O, 27 mM glycine and 220 mM Mannitol prepared in sterile water.

5 1.5x amount excipients refers to that the PBGD solution comprises 5.51 mM Na<sub>2</sub>HPO<sub>4</sub> x 2H<sub>2</sub>O, 40.5 mM glycine and 375 mM Mannitol prepared in sterile water, i.e. 1.5x of each of the components present in the 1x buffer.

2x excipients refers to that the PBGD solution comprises 7.34 mM Na<sub>2</sub>HPO<sub>4</sub> x 2H<sub>2</sub>O, 54 mM glycine and 500 mM Mannitol prepared in sterile water, , i.e. 2x of 10 each of the components present in the 1x buffer.

The original freeze-drying cycle is as described above.

The annealing freeze-drying cycle is as described above where the annealing step comprises raising the temperature to -10°C at keeping the sample at this temperature for 120 minutes before lowering it to -40°C again.

15 The extended annealing freeze-drying cycle is as described above where the annealing step comprises raising the temperature to -20°C at keeping the sample at this temperature for 420 minutes before lowering it to -40°C again.

Table 20:

Amount of excipients	Protein concentration (mg/ml)	Reconstitution time for different free-drying cycles		
		Original	Annealing	Extended annealing
1x	198	600	550	480
1x	175	540	500	450
1x	150	450	480	180
1x	125	330	100	10
1x	100	40	10	10
1x	80	25	10	10
1.5x	200	480	40	60
1.5x	175	220	10	10
1.5x	150	60	10	10
1.5x	125	15	10	10
1.5x	100	10	10	10
2x	200	120		20
2x	175	40		20

2x	150	20		10
2x	100	10		10

### Example 5

The effect of different modes of freeze-drying and/or the amount of excipients on  
5 the appearance of the freeze-dried product

Concentrated and freeze-dried solutions of PBGD were prepared as described in example 4 and references to the amount of excipients and the type of freeze-drying cycle has the same meaning as in example 4.

The following results were obtained by visual inspection of the freeze-dried  
10 products:

A: Comparison of three products prepared from solutions comprising respectively, 4.6 mg/ml 66.6 mg/ml and 109.4 mg/ml rhPBGD showed that the number of cracks in the freeze-dried product increased as concentration of rhPBGD increased.

15 B: Comparison of two products, prepared from a solution comprising 150 mg/ml rhPBGD, and comprising 1x and 1.5x amount of excipients showed that the number of cracks in the freeze-dried product was lower for the product which comprised 1.5x amount of excipients than the product comprising 1x amount of excipients.

20 C: Comparison of two freeze-dried products prepared from a 150 mg/ml rhPBGD solution, comprising 1x and 2x amount of excipients showed that the number of cracks in the freeze-dried product with 2x amount of excipients was lower than the product comprising the 1x amount of excipients.

D: Comparison of three freeze-dried products prepared from a 150 mg/ml rhPBGD  
25 solution by using the original, the annealing and the extended annealing freeze-drying cycle showed that the number of cracks in the freeze-dried product was lower in the product which was prepared according to the annealing freeze-drying cycle than in the product prepared according to the original freeze-drying cycle. Furthermore, the number of cracks in the product prepared according to the  
30 extended annealing freeze-drying cycle was lower than in the product prepared according to the annealing freeze-drying cycle.

E: Three freeze-dried products were prepared from a 150, 175 and 200 mg/ml, respectively, rhPBGD solution. The freeze-dried products each comprised 1.5x amount of excipients and they were freeze-dried with the annealing cycle. None of the freeze-dried products comprised any cracks.

5 F: Two freeze-dried rhPBGD products were prepared from a 150 mg/ml rhPBGD solution. One of them comprised 1x amount of excipients and was prepared according to the original freeze-drying cycle, while the other comprised 1.5x amount of excipients and was prepared according to the extended annealing freeze-drying cycle. The product comprising 1.5x amount of excipients and prepared  
10 according to the extended annealing freeze-drying cycle comprised fewer cracks than the product comprising 1x amount of excipients and prepared according to the original freeze-drying cycle.

G: Two freeze-dried rhPBGD products were prepared from a 150 mg/ml rhPBGD solution. One of them comprised 1x amount of excipients and was prepared  
15 according to the original freeze-drying cycle, while the other comprised 0.1% Tween 80 in combination with the 1x amount of excipients and was prepared according to the extended annealing freeze-drying cycle. The product comprising the 0.1% Tween 80 in combination with the 1x amount of excipients and which was prepared according to the extended annealing freeze-drying cycle comprised  
20 fewer cracks than the product which comprised 1x amount of excipients and which was prepared according to the original freeze-drying cycle.

### **Example 6**

The effect of recovery volume, the amount of excipients and the mode of freeze-drying on the stability of freeze-dried rhPBGD

Concentrated rhPBGD solutions freeze-dried samples were prepared as described in example 4.

The "bulk solution" is a concentrated solution of PBGD before freeze-drying.

Table 21 shows the results of rhPBGD solutions having the following  
30 characteristics with regard to the concentration of rhPBGD, amount of excipients (were the same definitions as in example 4 are used), the mode of freeze-drying (were the same definitions as in example 4 are used) and the ratio of the filling volume (fill. Vol which is the volume of the composition before it is freeze-dried) versus the recovery volume (Rec. vol which is the volume in which the freeze-  
35 dried product is resuspended):

## Solution 1:

- Approximately 5 mg/ml rhPBGD
- 1x amount of excipient
- Original freeze-drying cycle

5      • Fill.vol = Rec. vol

## Solution 2:

- Approximately 70 mg/ml rhPBGD
- 1x amount of excipient
- Original freeze-drying cycle

10     • Fill.vol = 2x Rec. vol

## Solution 3:

- Approximately 110 mg/ml rhPBGD
- 1x amount of excipient
- Original freeze-drying cycle

15     • Fill.vol = Rec. vol

## Solution 4:

- Approximately 70 mg/ml rhPBGD
- 1x amount of excipient
- Original freeze-drying cycle

20     • Fill.vol = 1.5x Rec. vol

## Solution 5:

- Approximately 90 mg/ml rhPBGD
- 2/3x amount of excipient
- Original freeze-drying cycle

25     • Fill.vol = 1.5x Rec. vol

## Solution 6:

- Approximately 60 mg/ml rhPBGD
- 1/2x amount of excipient
- Original freeze-drying cycle

30     • Fill.vol = 2x Rec. vol

## Solution 7:

- Approximately 110 mg/ml rhPBGD
- 1x amount of excipient
- Annealing freeze-drying cycle

35     • Fill.vol = Rec. vol

## Solution 8:

- Approximately 60 mg/ml rhPBGD
- 1x amount of excipient
- Annealing freeze-drying cycle

5        • Fill.vol = 2x Rec. vol

## Solution 9:

- Approximately 150 mg/ml rhPBGD
- 1x amount of excipient
- Annealing freeze-drying cycle

10      • Fill.vol = Rec. vol

## Solution 10:

- Approximately 150 mg/ml rhPBGD
- 1x amount of excipient
- Original freeze-drying cycle

15      • Fill.vol = Rec. vol

Although not shown in Table 21 the purity was also tested for each time point as was found to 100% in all cases.

For solution 2 at the week 4 and 9 time point and for solution 4 the week 9 time point a wrong recovery volume was used.

Table 21:

Solution	Measurin g point (week)	Fill. Vol (ml)	Rec. Vol (ml)	pH	Osmolalit y (mosmol/kg)	Protein concentr ation (mg/ml)	Activity (U/ml)	Specific activity (U/mg)
1	bulk							
	0	0.67	0.67	7.54	274	4.6	78	17.1
	2	0.67	0.67	7.22	274	4.6	85	17.8
	4	0.67	0.67	7.78	279	5.1	75	19.4
	7	0.67	0.67	7.87	284	5.1	68	14.5
	9	0.67	0.67	7.67	403	7.0	93	13.3
	bulk							
	0	0.67	0.335	7.64	525	113	1915	16.9
	2	0.67	0.335	7.63	459	93.6	1593	17.0
	4	0.67	0.67	7.75	264	64.6	1104	17.1
2	7	0.67	0.335	7.95	451	106.4	2106	19.8
	9	0.67	0.67	7.59	247	51.4	859	16.7
	bulk							
	0	0.67	0.67	7.75	274	99.9	1598	16.0
	2	0.67	0.67	7.64	269	91.4	1543	16.9
	4	0.67	0.67	7.68	274	101.2	1825	18.0
	7	0.67	0.67	7.71	278	103.4	2045	19.8
	9	0.67	0.67	7.67	274	88.3	1656	18.8
	bulk							
	0	0.67	0.45	7.64	448	113.8	1748	15.4

	2	0.67	0.45	7.63	411	86.4	1806	20.9
	4	0.67	0.45	7.77	362	109.9	1897	17.3
	7	0.67	0.45	7.90	379	95.2	686	(7.2)
	9	0.67	0.67	7.63	273	59.7	1090	18.3
5	bulk					91.0	1610	17.7
	0	0.67	0.45	7.65	296	119.4	2014	16.9
	2	0.67	0.45	7.61	285	112.3	2093	18.6
	4	0.67	0.45	7.90	292	125.1	2409	19.3
	7	0.67	0.45	7.88	297	116.4	1928	16.6
	9	0.67	0.45	7.34	278	102.5	1490	14.5
6	bulk					60.7	992	16.3
	0	0.67	0.335	7.63	295	112.6	1753	15.6
	2	0.67	0.335	7.60	288	86.9	1787	20.6
	4	0.67	0.335	7.83	287	116.4	2106	18.1
	7	0.67	0.335	8.20	299	109.7	695	(6.3)
	9	0.67	0.335	7.44	287	95.2	1636	17.2
7	bulk					116.4	1926	16.5
	0	0.67	0.67	7.56	275	101.1	1750	17.3
	2	0.67	0.67	7.51	276	93.4	1831	19.6
	4	0.67	0.67	7.60	270	101.6	1774	17.5
	7	0.67	0.67	7.53	283	102.2	1639	16.0
	9	0.67	0.67	7.46	274	89.9	960	10.7
8	bulk					64.5	1119	17.4
	0	0.67	0.335	7.52	511	100.7	1718	17.1
	2	0.67	0.335	7.51	459	99.3	1900	19.1

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	4	0.67	0.335	7.70	482	114.5	1913	16.7
	9	0.67	0.335	7.29	425	102.3	1650	16.1
9	bulk					165	3587	21.7
	0	0.60	0.60	7.71	309	121.4	2819	23.2
	4	0.60	0.60	7.74	—	140.3	2014	14.4
	7.5	0.60	0.60	7.61	292	135.9	1640	12.1
10	bulk					165	3587	21.7
	0	0.60	0.60	7.86	276	142.1	2397	16.9
	3	0.40	0.40	8.20	314	141.9	2381	16.8
	5	0.60	0.60	7.60	302	131.8	2304	17.5

**Example 7**Effect of different excipients on the stability of rhPBGD

rhPBGD was concentrated as described in example 4 and then the buffer was  
5 changed as to one of the four buffers described below. The products were then  
freeze-dried as described in example 4 with an original annealing step included  
and the stability of the samples were tested as described in example 6.

The effect of the following four formulations on the stability of rhPBGD was tested:

Formulation A (corresponds to solution 9 in example 6): 250 mM mannitol, 27 mM  
10 glycine and 3.67 mM Na<sub>2</sub>HPO<sub>4</sub>.

Formulation B: 250 mM mannitol, 27 mM glycine and 10 mM TRIS-HCL.

Formulation C: 250 mM mannitol, 27 mM glycine, 3.67 mM Na<sub>2</sub>HPO<sub>4</sub> and 0.1%  
Tween 80.

Formulation D: 221 mM mannitol, 29 mM sucrose, 27 mM glycine, 3.67 mM  
15 Na<sub>2</sub>HPO<sub>4</sub> and 0.1% Tween 80.

The results are shown in Table 22.

Formulatio n	Measurin g point (week)	Fill. Vol (ml)	Rec. Vol (ml)	pH	Osmolalit y (mosmol/ kg)	Protein concentr (mg/ml)	Activity (U/ml)	Specific activity (U/mg)
A	Bulk		7.69	366	165	3587	21.7	
	0	0.60	0.60	7.71	309	121.4	2819	23.2
	4	0.60	0.60	7.74	—	140.3	2014	14.4
	7.5	0.60	0.60	7.61	292	135.9	1640	12.1
B	Bulk		7.54	320	173	3595	20.8	
	0	0.60	0.60	7.58	284	148.1	3726	25.2
	3	0.60	0.60	7.57	280	165.4	2947	17.8
	4	0.60	0.60	7.69	—	167.5	2367	14.1
C	7.5	0.60	0.60	7.60	283	150.4	2235	14.9
	Bulk		7.40	338	178	3606	20.2	
	0	0.60	0.60	7.76	290	142.9	2662	18.6
	3	0.60	0.60	7.43	285	181.7	2332	12.8
D	4	0.60	0.60	7.42	—	173.1	1436	8.3
	6	0.60	0.60	7.55	274	156.6	1254	7.4
	7.5	0.60	0.60	7.34	274	141.5	1252	8.9
	Bulk		7.41	337	175	3869	22.1	
	0	0.60	0.60	7.80	292	127.5	2355	18.5
	3	0.60	0.60	7.35	288	143.9	1988	13.8
	4	0.60	0.60	7.26	—	159.3	1644	10.3
	6	0.60	0.60	7.30	281	135.7	1236	9.1
	7.5	0.60	0.60	7.28	282	125.7	1146	9.1

**CLAIMS:**

1. A composition comprising 10-50 mg/ml of alpha mannosidase and wherein less than 5% of the total amount of the alpha mannosidase in said composition is present in the form of aggregates of a dimer or multimer alpha mannosidase, and a carrier.

2. The composition of claim 1, wherein the alpha mannosidase comprises an amino acid sequence selected from the group consisting of:

- i) an amino acid sequence as defined by SEQ ID NO: 21; and
- ii) a functionally equivalent analogue of an amino acid sequence as defined in i), the amino acid sequence of said analogue being at least 75% identical over the full-length to the amino acid sequence as defined in i), and wherein

the functionally equivalent analogue in ii) comprises a domain or subsequence of the alpha-mannosidase which includes the necessary catalytic site to enable the domain or subsequence to exert the same enzymatic activity as the full-length alpha-mannosidase.