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(54) **Titre : PROCEDE DE DETERMINATION DE L'ACTIVITE BIOLOGIQUE DE LA NEUROTOXINE BOTULIQUE**
(54) **Title: METHOD FOR THE DETERMINATION OF BOTULINUM NEUROTOXIN BIOLOGICAL ACTIVITY**

(57) **Abrégé/Abstract:**

The present invention relates to means and methods for determining neurotoxin activity. Specifically, it relates to a polypeptide having caspase activity comprising a large subunit and a small subunit wherein said caspase further comprises a neurotoxin cleavage site which upon cleavage activates the caspase activity. Also encompassed are polynucleotides encoding said polypeptides as well as vectors or host cells comprising the polynucleotides. The present invention further relates to a method for determining neurotoxin activity in a sample based on the polypeptide of the invention as well as the use of said polypeptide for determining neurotoxin activity in a sample, in general.

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(54) Title: METHOD FOR THE DETERMINATION OF BOTULINUM NEUROTOXIN BIOLOGICAL ACTIVITY

(57) Abstract: The present invention relates to means and methods for determining neurotoxin activity. Specifically, it relates to a polypeptide having caspase activity comprising a large subunit and a small subunit wherein said caspase further comprises a neurotoxin cleavage site which upon cleavage activates the caspase activity. Also encompassed are polynucleotides encoding said polypeptides as well as vectors or host cells comprising the polynucleotides. The present invention further relates to a method for determining neurotoxin activity in a sample based on the polypeptide of the invention as well as the use of said polypeptide for determining neurotoxin activity in a sample, in general.

WO 2012/123370 A1

Method for the determination of Botulinum neurotoxin biological activity

[0001] The present invention relates to means and methods for determining neurotoxin activity. Specifically, it relates to a polypeptide having caspase activity comprising a large subunit and a small subunit wherein said caspase further comprises a neurotoxin cleavage site which upon cleavage activates the caspase activity. Also encompassed are polynucleotides encoding said polypeptides as well as vectors or host cells comprising the polynucleotides. The present invention further relates to a method for determining neurotoxin activity in a sample based on the polypeptide of the invention as well as the use of said polypeptide for determining neurotoxin activity in a sample, in general.

[0002] *Clostridium botulinum* and *Clostridium tetani* produce highly potent neurotoxins, i.e. botulinum toxins (BoNTs) and tetanus toxin (TeNT), respectively. These Clostridial neurotoxins specifically bind to neuronal cells and disrupt neurotransmitter release. Each toxin is synthesized as an inactive unprocessed approximately 150 kDa single-chain protein. The posttranslational processing involves formation of disulfide bridges, and limited proteolysis (nicking) by bacterial protease(s). Active dichain neurotoxin consists of two chains, an N-terminal light chain of approx. 50 kDa and a heavy chain of approx. 100 kDa linked by a disulfide bond. Neurotoxins structurally consist of three domains, i.e. the catalytic light chain, the heavy chain encompassing the translocation domain (N-terminal half) and the receptor binding domain (C-terminal half), see Krieglstein 1990, Eur J Biochem 188, 39; Krieglstein 1991, Eur J Biochem 202, 41; Krieglstein 1994, J Protein Chem 13, 49.

[0003] *Clostridium botulinum* secretes seven antigenically distinct serotypes designated A to G of the BoNTs. All serotypes together with the related TeNT secreted by *Clostridium tetani*, are zinc (Zn^{2+})-dependent endoproteases that block synaptic exocytosis by cleaving SNARE proteins and, in particular in the case of BoNT/A, C or E, SNAP-25. BoNTs cause, inter alia, the flaccid muscular paralysis seen in botulism, see Fischer 2007, PNAS 104, 10447.

[0004] Despite its toxic effects, BoNTs have been used as a therapeutic agents in a large number of diseases. BoNT serotype A (BoNT/A) was approved for human use in the United States in

1989 for the treatment of strabism, blepharospasm, and other disorders. It is commercially available as a protein preparation, for example, under the tradename BOTOX (Allergan Inc) under the tradename DYSPORT (Ipsen Ltd). For therapeutic application the complex is injected directly into the muscle to be treated. At physiological pH, the toxin is released from the protein complex and the desired pharmacological effect takes place. An improved BoNT/A preparation being free of complexing proteins is available under the tradename XEOMIN (Merz Pharmaceuticals GmbH).

[0005] BoNTs, in principle, weaken voluntary muscle strength and are, therefore, effective therapeutic agents for the therapy of diseases such as strabism, focal dystonia, including cervical dystonia, and benign essential blepharospasm or spasticity. They have been further shown to relief hemifacial spasm, and focal spasticity, and moreover, to be effective in a wide range of other indications, such as gastrointestinal disorders, hyperhidrosis, and cosmetic wrinkle correction, see Jost 2007, Drugs 67, 669.

[0006] The determination of the biological activity is important as a safety measure, for quality control and for quantification purposes. The mouse LD50 assay is currently the only reliable assay for quantifying the biological activity of neurotoxins and for assessing their therapeutic potential and/or their toxicity. Said assay is also accepted for quality control purposes during manufacture of neurotoxin. In the mouse LD50 bioassay, lethal and sub-lethal concentrations of a sample containing the neurotoxin polypeptide have to be injected into at least 120 animals. The number of killed animals over an observation period of 72 hours allows determining the neurotoxin polypeptide concentration in the sample. Apparent drawbacks of this assay are the high number of animals which will be sacrificed and the high level of stress and pain for said animals during the test.

[0007] In vitro assays which have been proposed so far are based on determining SNAP-25 cleavage in a cell free system or on neurotoxin exposure to primary neurons. However, these assay are less reliable and/or do not take into account all of the desired neurotoxin functions. Thus, at present, the LD50 bioassay described above is the only reliable assay which is described in the monograph for BoNT/A in the European pharmacopeia. However, there is a need for a reliable assay for measuring neurotoxin activity which avoids the drawbacks of the LD50 bioassay.

[0008] Therefore, the technical problem underlying the present invention could be seen in the provision of means and methods for complying with the aforementioned needs. The technical problem is solved by the embodiments characterized in the claims and herein described below.

[0009] Thus, the present invention relates to a polypeptide having caspase activity comprising a large subunit and a small subunit wherein said caspase further comprises a neurotoxin cleavage site which upon cleavage activates the caspase activity.

[0010] The term “polypeptide having caspase activity” as used herein refers to a polypeptide which has a cysteine protease activity and in particular a cysteine-dependent aspartate-directed protease activity. Polypeptides having caspase activity (or so-called “caspases”) are involved in cells in the programmed cell death (apoptosis) which occurs in many pathological and physiological processes including development. In a cellular context, caspases are arranged to operate in cascades. Accordingly, there are cascades which are activated by an external or internal stimulus (the so-called initiator or apical caspases). These initiator caspases subsequently activate further caspases by proteolytic cleavage (the so-called effector or executioner caspases). The effector caspases will then cleave other polypeptide substrates thereby triggering the apoptotic cell death in a cell. Initiator caspases are caspase 2, caspase 8, caspase 9 and caspase 10. Effector caspases are caspase 3, caspase 6 and caspase 7. The caspases caspase 4, caspase 5 and caspase 14 are enzymes which are involved in immunological processes and have not been characterized as initiator or effector caspases, respectively. Amino acid sequences encoding the aforementioned caspases are well known in the art (Yuan 1992, Development 116(2): 309-320; Ellis 1991, Annu Rev Cell Biol 7: 663-698; Yuan 1993, Cell 75(4): 641-652; Miura 1993, Cell 75(4): 653-660; Fuentes-Prior 2004, Biochem J 384: 201-232). In an aspect, human caspase 9 comprises an amino acid sequence as shown in SEQ ID NO: 6, human caspase 3 comprises an amino acid sequence as shown in SEQ ID NO: 7, human caspase 8 comprises an amino acid sequence as shown in SEQ ID NO: 8, human caspase 10 comprises an amino acid sequence as shown in SEQ ID NO: 9, human caspase 2 comprises an amino acid sequence as shown in SEQ ID NO: 10, human caspase 7 comprises an amino acid sequence as shown in SEQ ID NO: 11, and/or human caspase 6 comprises an amino acid sequence as shown in SEQ ID NO: 12.

[0011] Caspases as used herein also include polypeptides having caspase activity which have a variant amino acid sequence with respect to the aforementioned specific sequences shown in any one of SEQ ID NOs: 6 to 12. Said variant sequences comprise one or more amino acid substitutions, deletions and/or additions with respect to the specific sequences shown in any one of SEQ ID NOs: 6 to 12 referred to before. Moreover, such a variant polypeptide shall, in another aspect, comprise an amino acid sequence being at least 40%, at least 50%, at least 60%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 98% or at least 99% identical to the aforementioned specific amino acid sequence shown in any one of SEQ ID NOs: 6 to 12. The term "identical" as used herein refers to sequence identity characterized by determining the number of identical amino acids between sequences wherein the sequences are aligned so that the highest order match is obtained. It can be calculated using published techniques or methods codified in computer programs such as, for example, BLASTP or FASTA (Altschul 1990, J Mol Biol 215, 403). The percent identity values are, in one aspect, calculated over the entire amino acid sequence or over a sequence stretch of at least 50% of the query sequence. A series of programs based on a variety of algorithms is available to the skilled worker for comparing different sequences. In this context, the algorithms of Needleman and Wunsch or Smith and Waterman give particularly reliable results. To carry out the sequence alignments, the program PileUp (Higgins 1989, CABIOS 5, 151) or the programs Gap and BestFit (Needleman 1970, J Mol Biol 48; 443; Smith 1981, Adv Appl Math 2, 482), which are part of the GCG software packet (Genetics Computer Group 1991, 575 Science Drive, Madison, Wisconsin, USA 53711), may be used. The sequence identity values recited above in percent (%) are to be determined, in another aspect of the invention, using the program GAP over the entire sequence region with the following settings: Gap Weight: 50, Length Weight: 3, Average Match: 10.000 and Average Mismatch: 0.000, which, unless otherwise specified, shall always be used as standard settings for sequence alignments.

[0012] The caspases are expressed as inactive proenzymes (zymogens) consisting from the N-terminus to the C-terminus of (i) a prodomain, (ii) a small subunit and (iii) a large subunit. The prodomain of the initiator caspases contains interaction domains such as a CARD domain in caspases-2 and -9 or the death effector domain (DED) in caspases-8 and -10. These interaction domains enable the caspases to interact with polypeptides which initiate their activation. Some of these polypeptides which initiate the activation of the initiator caspase are, e.g., death receptors like Fas, TRAIL receptors and TNF receptor which can activate caspase-8 and -10. Substrates of the effector caspases on the other end of the caspase cascade are, e.g., nuclear lamins,

ICAD/DFF45 (inhibitor of caspase activated DNase or DNA fragmentation factor 45), PARP (poly-ADP ribose polymerase) or PAK2 (P 21-activated kinase 2).

[0013] Accordingly, in an aspect, effector caspase activity can be measured by cleavage of one or more of the aforementioned substrates including cell cycle proteins, DNA repair proteins, signaling molecules, cytoskeletal proteins and others. In an aspect, the effector caspase activity is measured by determining PARP cleavage. PARP comprises a DEVD motif which is recognized and cleaved by the effector caspase caspase 3. For measuring PARP cleavage several protease activity assays are commercially available.

[0014] Alternatively and in another aspect, caspase activity of an effector caspase can be determined by determining the amount of cell death which occurs in a cell population such as a cell culture. Apoptotic cell death can be measured by various well known techniques. In an aspect, DNA fragmentation is determined which typically occurs as so-called apoptotic laddering and is caused by regular cleavage of the genomic DNA in a cell which undergoes apoptosis. In another aspect, blebbing can be analyzed via imaging methods using a specific dye such as Höchst 33258. Moreover, and in a further aspect, the phospholipid distribution can be determined and, in an aspect, the phosphatidylserin distribution. The phosphatidylserin distribution can be determined by a phosphatidylserin binding protein such as annexin V. Imaging platforms for measuring apoptosis based on annexin V have been recently reported and are described in Tait 2008, J Nuclear Medicine 49(10): 1573-76; Jeppsen 2008, J Biol Chem 283: 6126-35; Tait 2006, J Nuclear Medicine 47: 1546-53. It will be understood that the aforementioned measures for determining apoptosis can also be combined.

[0015] The caspase activity of an initiator caspase can be determined, in an aspect, as described for the effector caspase activity in an in vivo system like a cell culture or an in vitro (i.e. cell-free) system comprising also effector caspases. Moreover, the initiator caspase activity, in an aspect, can be determined based on the cleavage of effector caspases as substrate of the said initiator caspases.

[0016] The caspase activity, in an aspect, can be determined in a cell-free in vitro system as set forth above. Such a cell free system may be a cellular fraction which comprises the substrates of the caspase. Alternatively, an artificial solution can be applied comprising said substrates and which provides conditions under which caspases are active. In another aspect, the caspase activity can be determined in vivo in a suitable host cell which expresses the polypeptide of the

present invention and which further comprises a biologically active neurotoxin polypeptide capable of cleaving the said polypeptide. As a result of the cleavage, the polypeptide of the present invention shall become activated and elicits apoptosis in the host cell. In an aspect, such an activity assay is also described in accordance with the method of the present invention elsewhere herein.

[0017] The term “neurotoxin cleavage site” as used herein refers to cleavage site which is recognized and cleaved by the endogenous protease of a neurotoxin polypeptide. Cleavage site which are recognized by the neurotoxin proteases are well known in the art (see, e.g., EP 1 926 744 B1). In principle, a neurotoxin cleavage site can be a cleavage site which naturally occurs in a substrate or which is an artificially designed cleavage site recognized and cleaved by the neurotoxin polypeptides protease. It will be understood that the properties of the neurotoxin cleavage site govern the kind of neurotoxin which can activate the polypeptide of the present invention. Neurotoxin polypeptides referred to herein, in an aspect, encompass BoNT/A, BoNT/B, BoNT/C1, BoNT/D, BoNT/E, BoNT/G, BoNT/F or TeNT all of which are well known in the art. For example, if a neurotoxin cleavage site is used which is specifically recognized and cleaved by BoNT/A, only the BoNT/A protease will be capable of activating the polypeptide of the present invention and, in particular, its caspase activity, whereas if a neurotoxin cleavage site is used which is specifically recognized and cleaved by BoNT/E, only the BoNT/E protease will be capable of activating the polypeptide of the present invention and, in particular, its caspase activity. In an aspect of the invention, the neurotoxin cleavage site is cleaved by mature BoNTs. In yet another aspect, it is cleaved by muteins of BoNTs, in an aspect, by muteins comprising or consisting of the BoNT light chain exhibiting the BoNT protease activity.

[0018] A neurotoxin cleavage site recognized and cleaved by the BoNT/A protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/A. In an aspect, such a protein is human SNAP25A or B or a homolog, paralog or ortholog thereof from rat, mouse, bovine, Danio, Carassius, Xenopus, Torpedo, Strongylocentrotus, Loligo, Lymnaea or Aplysia. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0019] A neurotoxin cleavage site recognized and cleaved by the BoNT/B protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/B. In an aspect, such a protein is human or mouse VAMP-1, VAMP-2 and VAMP-3/cellubrevin, bovine VAMP-2, rat VAMP-2 or VAMP-3, chicken VAMP-1, VAMP-2 or VAMP-3, Torpedo VAMP-1,

Strongylocentrotus VAMP, Drosophila sybA, synB, synC, synD, or syn, Hirudo VAMP, Xenopus VAMP-2 or VAMP-3, Danio VAMP-1 or VAMP-2, Loligo VAMP, Lymnaea VAMP, Aplysia VAMP or Caenorhabditis SNB1-like or any ortholog, paralog or homolog thereof. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0020] A neurotoxin cleavage site recognized and cleaved by the BoNT/C1 protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/C1. In an aspect, such a protein is human and mouse Syntaxin 1A, Syntaxin 1B1, Syntaxin 2-1, Syntaxin 2-2, Syntaxin 2-3, Syntaxin 3A or Syntaxin 1B2, bovine or rat Syntaxin 1A, Syntaxin 1B1 or Syntaxin 1B2, rat Syntaxin 2 or Rat syntaxin 3, mouse Syntaxin 1A, Syntaxin 1B1, Syntaxin 1B2, Syntaxin 2, Syntaxin 3A, Syntaxin 3B or Syntaxin 3C, chicken Syntaxin 1A or Syntaxin 2; Xenopus Syntaxin 1A or Syntaxin 1B, Danio Syntaxin 1A, Syntaxin 1B or Syntaxin 3, Torpedo Syntaxin 1A or Syntaxin 1B, Strongylocentrotus Syntaxin 1A or Syntaxin 1B, Drosophila Syntaxin 1A or Syntaxin 1B, Hirudo Syntaxin 1A or Syntaxin 1B, Loligo Syntaxin 1A or Syntaxin 1B, Lymnaea Syntaxin 1A or Syntaxin 1B or any ortholog, paralog or homolog thereof. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0021] A neurotoxin cleavage site recognized and cleaved by the BoNT/D protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/D. In an aspect, such a protein is human or mouse VAMP-1, VAMP-2 and VAMP-3/cellubrevin, bovine VAMP-2, rat VAMP-2 or VAMP-3, chicken VAMP-1, VAMP-2 or VAMP-3, Torpedo VAMP-1, Strongylocentrotus VAMP, Drosophila sybA, synB, synC, synD, or syn, Hirudo VAMP, Xenopus VAMP-2 or VAMP-3, Danio VAMP-1 or VAMP-2, Loligo VAMP, Lymnaea VAMP, Aplysia VAMP or Caenorhabditis SNB1-like or any ortholog, paralog or homolog thereof. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0022] A neurotoxin cleavage site recognized and cleaved by the BoNT/E protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/E. In an aspect, such a protein is, such a protein is human SNAP-25A or B or a homolog, paralog or ortholog thereof from rat, mouse, bovine, Danio, Carassius, Xenopus, Torpedo, Strongylocentrotus, Loligo, Lymnaea or Aplysia. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0023] A neurotoxin cleavage site recognized and cleaved by the BoNT/F protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/F. In an aspect, such a protein is, such a protein is human or mouse VAMP-1, VAMP-2 and VAMP-3/cellubrevin, bovine VAMP-2, rat VAMP-2 or VAMP-3, chicken VAMP-1, VAMP-2 or VAMP-3, Torpedo VAMP-1, Strongylocentrotus VAMP, Drosophila sybA, synB, synC, synD, or syn, Hirudo VAMP, Xenopus VAMP-2 or VAMP-3, Danio VAMP-1 or VAMP-2, Loligo VAMP, Lymnaea VAMP, Aplysia VAMP or Caenorhabditis SNB1-like or any ortholog, paralog or homolog thereof. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0024] A neurotoxin cleavage site recognized and cleaved by the BoNT/G protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by BoNT/G. In an aspect, such a protein is, such a protein is human or mouse VAMP-1, VAMP-2 and VAMP-3/cellubrevin, bovine VAMP-2, rat VAMP-2 or VAMP-3, chicken VAMP-1, VAMP-2 or VAMP-3, Torpedo VAMP-1, Strongylocentrotus VAMP, Drosophila sybA, synB, synC, synD, or syn, Hirudo VAMP, Xenopus VAMP-2 or VAMP-3, Danio VAMP-1 or VAMP-2, Loligo VAMP, Lymnaea VAMP, Aplysia VAMP or Caenorhabditis SNB1-like or any ortholog, paralog or homolog thereof. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0025] A neurotoxin cleavage site recognized and cleaved by the TeNT protease, in an aspect of the invention, is derived from a protein that is sensitive to cleavage by TeNT. In an aspect, such a protein is human or mouse VAMP-1, VAMP-2 and VAMP-3/cellubrevin, bovine VAMP-2, rat VAMP-2 or VAMP-3, chicken VAMP-1, VAMP-2 or VAMP-3, Torpedo VAMP-1, Strongylocentrotus VAMP, Drosophila sybA, synB, synC, synD, or syn, Hirudo VAMP, Xenopus VAMP-2 or VAMP-3, Danio VAMP-1 or VAMP-2, Loligo VAMP, Lymnaea VAMP, Aplysia VAMP or Caenorhabditis SNB1-like or any ortholog, paralog or homolog thereof. Suitable cleavage sites derived from said proteins are disclosed in EP 1 926 744 B1.

[0026] A neurotoxin cleavage site recognized and cleaved by the BoNT proteases, in another aspect of the invention, is derived from the autocatalytic cleavage sites found in the BoNT proteins. In aspects, a neurotoxin cleavage site to be used in accordance with the present invention and which is derived from the autocatalytic cleavage site of a given BoNT or TeNT comprises at least 6, at least 8, at least 10 or at least 15 consecutive residues of including the

BoNT/A residues 250Tyr-251Tyr, the BoNT/B residues 256Phe-257Phe, the BoNT/C1 residues 257Phe-258Tyr, the BoNT/D residues 257Phe-258Phe, the BoNT/E residues 239Pro-240Leu, the BoNT/F residues 254Pro-255Leu, the BoNT/G residues 256Phe-257Phe, the TeNT residues 259Ile-260Tyr, the BoNT/A residues Phe266-Gly267, the BoNT/B residues Phe272-Gly273, the BoNT/C1 residues Phe273-Gly274, the BoNT/D residues Phe273-Gly274, the BoNT/E residues Phe255-Gly256, the BoNT/F residues Phe270-Gly271, the BoNT/G residues Phe272-Gly273 or the TeNT residues Phe275-Gly276. Suitable cleavage sites derived from said BoNTs and TeNT are disclosed in EP 1 926 744 B1.

[0027] In an aspect of the polypeptide of the present invention, said neurotoxin cleavage site is a cleavage site recognized and cleaved by the BoNT/A protease. In an aspect, said cleavage site is shown in any one of SEQ ID NO: 1 to 5.

[0028] In a further aspect of the polypeptide of the present invention, said neurotoxin cleavage site is a cleavage site recognized and cleaved by the BoNT/B, BoNT/C1, BoNT/D, BoNT/E, BoNT/F, BoNT/G or TeNT protease.

[0029] In an aspect of the polypeptide of the present invention, said neurotoxin cleavage site is located between the C-terminal proximal region of the large subunit and the N-terminal proximal region of the small subunit. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids C170 to D175, L168 to E173, Q161 to D175, or Q161 to E173 of the large subunit of caspase 3 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S176 to V190 or S176 to C184 of the small subunit of caspase 3. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids V174 to D179, H172 to V177, Q165 to D179, or Q165 to V177 of the large subunit of caspase 6 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S180 to A194 or S180 to V188 of the small subunit of caspase 6. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids D193 to D198, L191 to Q196, Q184 to D198, or Q184 to Q196 of the large subunit of caspase 7 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S199 to V213 or S199 to R207 of the small subunit of caspase 7. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids K369 to D374, Y367 to E372, Q360 to

D374, or Q360 to E372 of the large subunit of caspase 8 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S375 to D389 or S375 to T383 of the small subunit of caspase 8. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids P367 to D372, I365 to E370, Q358 to D372, or Q358 to E370 of the large subunit of caspase 10 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids A373 to A386 or A373 to Q380 of the small subunit of caspase 10. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids H310 to D315, K308 to E313, Q301 to D315, or Q301 to E313 of the large subunit of caspase 9 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids A316 to T330 or A316 to I324 of the small subunit of caspase 9. In a further aspect, said C-terminal proximal region of the large subunit consists the amino acids corresponding to amino acids R311 to D316, T309 to Q314, Q302 to D316, or Q302 to Q314 of the large subunit of caspase 2 and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids G317 to T331 or G317 to K325 of the small subunit of caspase 2.

[0030] In another aspect of the polypeptide of the present invention, said polypeptide further comprises a prodomain. In an aspect, the prodomain comprises amino acids 1 to 29 of caspase 3, amino acid 1 to 24 of caspase 7, amino acids 1 to 24 of caspase 6, amino acids 1 to 217 of caspase 8, amino acids 1 to 226 of caspase 10, amino acids 1 to 139 of caspase 9 or amino acids 1 to 153 of caspase 2. In an aspect, said neurotoxin cleavage site is located between the C-terminal proximal region of the prodomain and the N-terminal proximal region of the large subunit. In a further aspect, the said C-terminal proximal region of the prodomain consists of the amino acids corresponding to amino acids S29 to D34 of the large subunit of caspase 3 and said N-terminal proximal region of the large domain consists of the amino acids corresponding to amino acids N35 to D40 of the large subunit of caspase 3. In an aspect, the C-terminal proximal region of the prodomain for caspase 3, thus, encompasses amino acids 29 to 34 and the N-terminal proximal region of the large domain consists the amino acids 35 to 40, the C-terminal proximal region of the prodomain for caspase 6 encompasses amino acids 24 to 29 and the N-terminal proximal region of the large domain consists the amino acids 30 to 35, the C-terminal proximal region of the prodomain for caspase 7 encompasses amino acids 24 to 29 and the N-terminal proximal region of the large domain consists the amino acids 30 to 35, the C-terminal proximal region of the prodomain for caspase 8 encompasses amino acids 217 to 222 and the N-

terminal proximal region of the large domain consists the amino acids 223 to 228, the C-terminal proximal region of the prodomain for caspase 9 encompasses amino acids 153 to 158 and the N-terminal proximal region of the large domain consists the amino acids 159 to 164, the C-terminal proximal region of the prodomain for caspase 10 encompasses amino acids 231 to 236 and the N-terminal proximal region of the large domain consists the amino acids 237 to 242.

[0031] As discussed elsewhere herein, in another aspect of the polypeptide of the present invention, said polypeptide is an effector caspase. In an aspect, said effector caspase is selected from the group consisting of: caspase 3, caspase 6 and caspase 7.

[0032] In another aspect, the caspase from which the polypeptide of the present invention is derived by introducing a neurotoxin cleavage site is caspase 3.

[0033] In an further aspect, the polypeptide of the present invention comprises an amino acid sequence as shown in any one of SEQ ID NOs: 6 to 10 or is a variant thereof as described elsewhere herein retaining caspase activity and the neurotoxin cleavage site which upon cleavage activates the caspase activity.

[0034] As discussed also elsewhere herein, in a further aspect of the polypeptide of the present invention, said polypeptide is an initiator caspase. In an aspect, said initiator caspase is selected from the group consisting of: caspase 2, caspase 8, caspase 9 and caspase 10.

[0035] The present invention further contemplates a polynucleotide encoding the polypeptide of the present invention.

[0036] The term “polynucleotide” as used herein refers to single- or double-stranded DNA molecules as well as to RNA molecules. Encompassed by the said term is genomic DNA, cDNA, hnRNA, mRNA as well as all naturally occurring or artificially modified derivatives of such molecular species. The polynucleotide may be in an aspect a linear or circular molecule. Moreover, in addition to the nucleic acid sequences encoding the polypeptide of the present invention, a polynucleotide of the present invention may comprise additional sequences required for proper transcription and/or translation such as 5'- or 3'-UTR sequences. The nucleic acid sequences encoding the polypeptide of the present invention can be derived from the polypeptide sequences by a skilled artisan without further ado. In light of the degeneracy of the genetic code,

optimized codons may be used in the nucleic acid sequences encoding the polypeptide of the present invention in the polynucleotide. Thereby, optimal expression in, e.g., a host cell of the present invention can be achieved.

[0037] The present invention furthermore pertains to a vector comprising the polynucleotide of the present invention.

[0038] The term “vector”, preferably, encompasses phage, plasmid, viral or retroviral vectors as well as artificial chromosomes, such as bacterial or yeast artificial chromosomes. Moreover, the term also relates to targeting constructs which allow for random or site-directed integration of the targeting construct into genomic DNA. Such target constructs, preferably, comprise DNA of sufficient length for either homologous or heterologous recombination as described in detail below. The vector encompassing the polynucleotides of the present invention, in an aspect, further comprises selectable markers for propagation and/or selection in a host cell. The vector may be incorporated into a host cell by various techniques well known in the art. For example, a plasmid vector can be introduced in a precipitate such as a calcium phosphate precipitate or rubidium chloride precipitate, or in a complex with a charged lipid or in carbon-based clusters, such as fullerenes. Alternatively, a plasmid vector may be introduced by heat shock or electroporation techniques. Should the vector be a virus, it may be packaged in vitro using an appropriate packaging cell line prior to application to host cells. Retroviral vectors may be replication competent or replication defective. In the latter case, viral propagation generally will occur only in complementing host/cells. Moreover, in an aspect of the invention, the polynucleotide is operatively linked to expression control sequences allowing expression in prokaryotic or eukaryotic host cells or isolated fractions thereof in the said vector. Expression of the polynucleotide comprises transcription of the polynucleotide into a translatable mRNA. Regulatory elements ensuring expression in host cells are well known in the art. In an aspect, they comprise regulatory sequences ensuring initiation of transcription and/or poly-A signals ensuring termination of transcription and stabilization of the transcript. Additional regulatory elements may include transcriptional as well as translational enhancers. Possible regulatory elements permitting expression in prokaryotic host cells comprise, e.g., the lac-, trp- or tac-promoter in *E. coli*, and examples for regulatory elements permitting expression in eukaryotic host cells are the AOX1- or the GAL1- promoter in yeast or the CMV-, SV40-, RSV-promoter (Rous sarcoma virus), CMV-enhancer, SV40-enhancer or a globin intron in mammalian and

other animal cells. Moreover, inducible expression control sequences may be used in an expression vector encompassed by the present invention. Such inducible vectors may comprise tet or lac operator sequences or sequences inducible by heat shock or other environmental factors. Suitable expression control sequences are well known in the art. Beside elements which are responsible for the initiation of transcription such regulatory elements may also comprise transcription termination signals, such as the SV40-poly-A site or the tk-poly-A site, downstream of the polynucleotide. In this context, suitable expression vectors are known in the art such as Okayama-Berg cDNA expression vector pcDV1 (Pharmacia), pBluescript (Stratagene), pCDM8, pRc/CMV, pcDNA1, pcDNA3 (Invitrogen) or pSPORT1 (Invitrogen). Preferably, said vector is an expression vector and a gene transfer or targeting vector. Expression vectors derived from viruses such as retroviruses, vaccinia virus, adeno-associated virus, herpes viruses, or bovine papilloma virus, may be used for delivery of the polynucleotide or vector of the invention into a targeted cell population. Such approaches can also be used for gene therapy. Methods which are well known to those skilled in the art can be used to construct recombinant viral vectors; see, for example, the techniques described in Sambrook, Molecular Cloning A Laboratory Manual, Cold Spring Harbor Laboratory (1989) N.Y. and Ausubel, Current Protocols in Molecular Biology, Green Publishing Associates and Wiley Interscience, N.Y. (1994).

[0039] Moreover, encompassed by the present invention is a host cell comprising the polypeptide, the polynucleotide or the vector of the present invention.

[0040] The term "host cell" as used herein as used herein encompasses prokaryotic and eukaryotic host cells. In an aspect the host cell is a bacterial cell. In one aspect, the said bacterial host cell is an E.coli host cell or a clostridial host cell, in an aspect a clostridium botulinum host cell. Such a bacterial host cell may be used, e.g., for reproduction of the polynucleotide or the vector of the present invention. A eukaryotic host cell, in an aspect, is a cell which comprises the polypeptide and either the polynucleotide or the vector of the present invention wherein said polynucleotide or vector are expressed in the host cell in order to generate the polypeptide. In an aspect, the eukaryotic host cell may be a cell of a eukaryotic host cell line which stably expresses the polynucleotide of the invention. In another aspect, the host cell is a eukaryotic host cell which has been transiently transfected with the polynucleotide or vector of the invention and which expresses the polynucleotide of the invention. A host cell according to the present invention, in an aspect, further comprises substrates for the caspase activity of the polypeptide of

the invention. Moreover, in another aspect, the host cell is capable of responding to the caspase activity conferred by the cleaved polypeptide of the present invention by a change of the cellular physiology, in an aspect by apoptotic cell death or by at least the activation of a cascade which is capable of inducing apoptosis. In an aspect, said change of cellular physiology can be detected by a change of cellular morphology, by DNA degradation, in aspect apoptotic laddering, and/or by cleavage of substrates of the apoptotic caspase cascade including nuclear lamins, ICAD/DFF45 (inhibitor of caspase activated DNase or DNA fragmentation factor 45), PARP (poly-ADP ribose polymerase) or PAK2 (P 21-activated kinase 2). In an aspect the host cell is a eukaryotic host cell, in another aspect a mammalian host cell and in yet another aspect a cell which is capable of uptaking neurotoxin polypeptides. In an aspect, a cell capable of uptaking neurotoxin polypeptides can be a cell produces endogenously all necessary components for the neurotoxin polypeptide uptake. In an aspect, the cell is a neuronal cell. In another aspect, a cell capable of uptaking neurotoxin polypeptides is a cell which has been genetically engineered to produce the components necessary for the neurotoxin polypeptide uptake. How such cells can be genetically engineered by molecular biology techniques is well known to the skilled person.

[0041] In an aspect of the host cell of the present invention, said host cell is selected from the group consisting of: primary neuronal cells, cell line N1E-11, cell line Neuro2a, cell line PC12, and cell line SH-SY5Y.

[0042] The present invention relates to a method for determining neurotoxin activity in a sample comprising the steps of:

- (a) contacting the polypeptide of the present invention with a sample suspected to comprise neurotoxin activity; and
- (b) measuring caspase activity of the polypeptide, whereby neurotoxin activity in the sample is determined.

[0043] The method of the present invention can be assisted by automation. Specifically, in an aspect, step a) and /or b) may be assisted by robotic devices and automated systems for measuring the caspase activity. Suitable systems are known in the art and depend on the type of response to be determined. Moreover, the method may comprise additional steps pertaining to the sample preparation or generation of the polypeptide of the present invention.

[0044] The term “contacting” as used herein refers to bringing at least two different compounds in physical proximity as to allow physical and/or chemical interaction of said compounds. In the aforementioned method, the polypeptide according to the present invention is contacted with a sample suspected to comprise a biologically active neurotoxin polypeptide. The polypeptide shall be contacted for a time and under conditions sufficient to allow cleavage of the neurotoxin cleavage site in the polypeptide of the present invention by the neurotoxin polypeptide comprised by the sample. Contacting as used herein, in an aspect occurs in a host cell of the present invention containing the polypeptide of the present invention. Thus, in an aspect, said polypeptide is comprised by a host cell and, in an aspect, the host cell of the present invention. The said time and conditions will dependent on the amount of neurotoxin polypeptide comprised by the sample as well as on the uptake of the neurotoxin polypeptide by the host cell. The person skilled in the art is well aware of which conditions need to be applied dependent on the host cell, kind of sample, and kind of neurotoxin which shall be determined. In another aspect, contacting occurs in a cell free system comprising the polypeptide of the invention as well as a substrate of the polypeptide of the present invention and/or other caspases. Th cell free system shall allow for measuring the activity of the polypeptide of the present invention upon contacting the system with a sample and, thus, allows for determining the neurotoxin activity in said sample.

[0045] The term “sample” refers to a sample suspected to comprise neurotoxin polypeptide. The sample, in an aspect, is an aqueous solution. Such a sample may be a biological sample or may be a sample of an artificially generated aqueous solution. Such solutions, in an aspect, are obtained at different stages during neurotoxin manufacture, either for quality control and/or activity determination/specification purposes or for safety control. It is envisaged that the neurotoxin present in the said sample shall exhibit at least the neurotoxin protease activity. In another aspect, the neurotoxin is fully biologically active. In an aspect the said fully biologically active neurotoxin is required for entering the cell and for activating the read out based on the caspase polypeptide of the present invention. Accordingly, such a fully biologically active neurotoxin is to be applied if a host cell is to be contacted with the sample to be analyzed by the method of the invention. In another aspect, the sample to be applied for the method of the invention comprises neurotoxin polypeptides or fragments thereof which merely exhibit neurotoxin protease activity. Such neurotoxin polypeptides or fragments are, in an aspect, muteins of neurotoxin polypeptides comprising or consisting essentially of a proteolytically active light chain. It is to be understood that samples comprising neurotoxin polypeptides or

fragments thereof which merely exhibit neurotoxin protease activity shall be used if the sample is to be contacted to a cell free system as specified elsewhere herein in detail.

[0046] The caspase activity is measured by determining cleavage of a substrate of the caspase activity conferred by the polypeptide of the present invention. The substrate cleavage can be measured, in an aspect, by determining the cleaved substrate directly. In a further aspect, the cleavage of the substrate is determined by PAGE-based techniques, by immunofluorescent-based techniques such as FRET or flow cytometry, by antibody-based techniques such as Western blotting or ELISA, by size exclusion chromatography, HPLC coupled to a suitable detector, or by spectroscopic techniques such as mass spectroscopy or NMR spectroscopy. In another aspect, the caspase activity is determined indirectly, i.e. by determining a process downstream of the cleavage of the substrate. Since the caspase cascade activated by the polypeptide of the present invention in a host cell, in an aspect, results in apoptosis, its activity results in detectable changes of the cellular physiology and, finally, in apoptotic cell death. A change of the cellular physiology can be detected by a change of cellular morphology, by DNA fragmentation, in aspect apoptotic laddering, and/or by cleavage of substrates of the apoptotic caspase cascade including cell cycle proteins, DNA repair proteins, signaling molecules, cytoskeletal proteins and others. In an aspect, the substrate is one or more of the following substrates: nuclear lamins, ICAD/DFF45 (inhibitor of caspase activated DNase or DNA fragmentation factor 45), PARP (poly-ADP ribose polymerase) or PAK2 (P 21-activated kinase 2).

[0047] The amount of neurotoxin polypeptide in a sample can be determined quantitatively or qualitatively. For a quantitative detection, in an aspect, the measured amount can be compared to a calibration curve which is to be established by subjecting calibration samples having predetermined amounts of the neurotoxin polypeptide to be determined in the method of the present invention.

[0048] In an aspect of the method of the present invention, said caspase activity is measured by determining cleavage of at least one substrate of the polypeptide in vivo or in vitro. In an aspect, said substrate is at least one effector caspase. The cleavage of an effector caspase as substrate can be achieved by using an initiator caspase activity in the polypeptide of the present invention. The cleavage of an effector caspase as substrate by the polypeptide of the present invention, in an aspect, results in an amplification of the original caspase activity. Accordingly, such a

polypeptide of the present invention has a high sensitivity also for low amounts of neurotoxin polypeptide.

[0049] Specifically, it is envisaged in the method of the present invention to measure the caspase activity by determining apoptosis in a host cell culture comprising host cells expressing the polypeptide of the present invention having caspase activity. A host cell culture to be used in this context may be a neuronal host cell culture comprising neuronal cells which are capable to take up the neurotoxin polypeptide properly. To this end, the caspase activity of the polypeptide of the present invention will be activated after the host cell in the host cell culture has been contacted to a neurotoxin polypeptide containing sample. The neurotoxin containing sample can be derived either from medicament comprising the neurotoxin polypeptide or a cellular extract from Botulinum bacteria or host cells which are genetically engineered to express a neurotoxin polypeptide and which are used for the production of such a medicament. The biologically active neurotoxin of the sample will enter the said host cell and will subsequently activate the polypeptide of the invention comprising the respective cleavage site for the neurotoxin protease. The activated polypeptide of the invention having caspase activity will then activate the caspase cascade and, thus, will induce apoptosis in the host cell. Apoptosis of the host cell can then be measured as described in detail elsewhere herein. Specifically, apoptosis is measured by determining cellular and subcellular morphology of the cells by imaging techniques including the determination of blebbing using the dye Höchst 33258.

[0050] As will be understood from the above, the present invention in general relates to the use of the polypeptide, the polynucleotide, the vector or the host cell of the present invention for determining neurotoxin activity in a sample.

[0051] Furthermore, a kit for determining neurotoxin activity is provided in accordance with the present invention. Said kit comprises the polypeptide, the polynucleotide, the vector or the host cell of the present invention.

[0052] The term “kit” as used herein refers to a collection of means comprising the polypeptide, the polynucleotide, the vector and/or the host cell of the present invention which are provided in separate or common vials in a ready to use manner for carrying out the method of the present

invention. In an aspect, the kit comprises additional means for carrying out the method of the present invention, in an aspect, calibration standard solutions comprising neurotoxin polypeptide and/or means for measuring the caspase activity such as detection agents for determining cleavage of caspase substrates or agents for determining apoptosis in a cell. Furthermore, in an aspect, the kit comprises instructions for carrying out the method of the present invention. These instructions can be provided as a manual or can be in the form of a computer-implementable algorithm on a data storage medium which upon implementation is capable of governing one or more steps of the method of the invention.

[0053]

FIGURES

[0054] **Figure 1:** Caspases are constitutively expressed as enzymatically inactive zymogens. In case of Caspase 3, proCaspase-3 is a 32 kDa protein, which undergoes cleavage by initiator caspases Caspases 8 or 9 and autoprocessing into a larger and a smaller fragment of 17 and 12 kDa size. They form the enzymatically active heterodimer/tetramer which cleaves with some preference after DEVD sequence motifs. A typical substrate would be PARP which is cleaved into a 85kDa fragment and minor fragments and is inactivated. Active caspase-3 cleaves a large number of substrates and can be inhibited with small peptides using this sequence preference linked to alkylating structures such as zDEVD-fluoromethylketone. A SNAP25 sequence recognized and cleaved by BoNT/A, C or E or BoNT with mutated sequences is inserted between the prodomain and the large subunit or, between the large and the small subunit in order to allow BoNT/A, C or E or BoNT with mutated sequences to activate caspase 3 by cleavage at this site.

[0055] **Figure 2:** Test-expression of pTZE02 / Casp3.1 in different E. coli expression strains SDS-PAGE analysis. Gel 12%, stained with Coomassie Blue. Selected marker sizes are depicted to the left. To clearly relate bands in the Coomassie stained gel to the Casp 3.1 target and estimate the amount of soluble compared to insoluble target, western blot analysis with anti-Strep-Tag antibody was performed.

[0056] **Figure 3:** Test-expression of pTZE02 / Casp3.1 in different E. coli expression strains Western-blot analysis. Gel 12%, detection with anti Strep antibody. Selected marker sizes are depicted to the left. The western-blot analysis revealed the presence of a protein running between the 25 and the 35 kDa molecular weight marker band in the soluble and the insoluble protein fraction of all tested expression conditions. The BL21(DE3) as well as the BL21(DE3) /pGroESEL expression only showed a very weak signal detected in the soluble protein fraction with the Strep-Tag antibody. The detected protein band in the Rosetta(DE3) / pRARE2 and the Rosetta(DE3) / pLys expression corresponding with the expected molecular weight (30,4 kDa) of the translated Casp3.1 protein revealed, that at least 20-30% of the target should be present in a soluble form.

[0057] **Figure 4:** Test-expression of pTZE44 / Casp3.1 in different E. coli expression strains SDS-PAGE analysis. Gel 12%, stained with Coomassie Blue. Selected marker sizes are depicted to the left. To clearly identify MBP-Casp 3.1-fusion protein bands in the Coomassie stained gel and estimate the amount of soluble compared to insoluble target, western blot analysis was performed.

[0058] **Figure 5:** Test-expression of pTZE44 / Casp3.1 in different E. coli expression strains Western-blot analysis. Gel 12%, detection with anti Strep antibody. Selected marker sizes are depicted to the left.

[0059] **Figure 6:** Test-expression of pTZE02 / Casp3.1 in E. coli Rosetta(DE3) / pRARE2 SDS-PAGE analysis. Gel 12%, stained with Coomassie Blue. Selected marker sizes are depicted to the left.

[0060] **Figure 7:** Test-expression of pTZE02 / Casp3.1 in E. coli Rosetta(DE3) / pRARE2 Western-blot analysis. Gel 12%, detection with anti Strep antibody. Selected marker sizes are depicted to the left.

[0061] **Figure 8:** Test-expression of pTZE02 / Casp3.1 in E. coli Rosetta(DE3) / pLys SDS-PAGE analysis. Gel 12%, stained with Coomassie Blue. Selected marker sizes are depicted to the left.

[0062] **Figure 9:** Test-expression of pTZE02 / Casp3.1 in E. coli Rosetta(DE3) / pLys Western-blot analysis. Gel 12%, detection with anti Strep antibody. Selected marker sizes are depicted to the left.

[0063] **Figure 10:** Test-expression of pTZP01 / Casp3.1 in P. pastoris X33, KM71 and GS115 SDS-PAGE analysis. Gel 12%, stained with Coomassie Blue.

[0064] **Figure 11:** Test-expression of pTZP01 / Casp3.1 in P. pastoris X33, KM71 and GS115 Western-blot analysis. Gel 12%, detection with anti Strep antibody. Selected marker sizes are depicted to the left.

[0065] **Figure 12:** Test-expression of pHILD2 / Casp3.1 in P. pastoris KM71 and GS115 Left panel: SDS-PAGE analysis. Gel 12%, stained with Coomassie Blue. Right panel: Western-blot analysis. Gel 12%, detection with anti Strep antibody. Selected marker sizes are depicted to the left.

[0066] **Figure 13:** SDS PAGE and Western blot analysis of cleavage reaction products induced by BoNT/A.

EXAMPLES

[0067] **Example 1:** Cloning of E. coli constructs (pTZ_E02_Casp3.1 and pTZ_E44_Casp3.1)

[0068] This construct is a pET24d based vector derivative, the final construct encodes for Procaspase 3.1 with a C-terminal Streptag II. The following Cloning strategy was applied: Procaspase 3.1 was PCR-amplified from plasmid MRZ_Casp3.1 with the following primers:

1369_Casp3.1_BsmBI_fp AACGTCTCTGATGAACAGCTACAAGATGGACTACCC (SEQ ID NO: 13)

1369_Casp3.1_2Stop_AscI_rp AAGGCGCGCCTATTATTTTCGAACTGCGGGTGGCTC (SEQ ID NO: 14)

[0069] Procaspase 3.1 was subcloned into pTZE02 using the restriction sites AscI /BsmBI. Positive clones were screened by PCR and plasmid DNA was isolated. The cloned target

sequence of the final construct was verified via sequencing. The pTZ_E44_Casp3.1 construct consists of ssMBP (Maltose binding protein with signal sequence for periplasmatic expression) fused to Procaspase 3.1. The final construct encodes for a periplasmatic expressed MBP-Procaspase 3.1-fusionprotein with a C-terminal Streptag II. The MBP fusion partner can be cleaved from the Procaspase 3.1 part using the serin protease factor Xa yielding native, Streptag-tagged Procaspase 3.1. The following Cloning strategy was applied: Procaspase 3.1 was PCR-amplified from plasmid MRZ_Casp3.1 with the following primers: 1369_Casp3.1_BsmBI_fp and 1369_Casp3.1_2Stop_AscI_rp. Procaspase 3.1 was subcloned into pTZE44 using the restriction sites AscI /BsmBI. Positive clones were screened by PCR and plasmid DNA was isolated. The cloned target sequence of the final construct was verified via sequencing.

[0070] **Example 2:** Cloning of *P. pastoris* constructs pTZ_P01_Casp3.1 and pHIL-D2_Casp3.1

[0071] The pTZ_P01_Casp3.1 construct is a pPICZalphaA based vector derivative carrying a secretion signal (α -factor). The final construct will be secreted as Procaspase 3.1 with a C-terminal Streptag II. The following cloning strategy was applied: Procaspase 3.1 was PCR-amplified from plasmid MRZ_Casp3.1 with the following primers: 1369_Casp3.1_BsmBI_fp and 1369_Casp3.1_2Stop_AscI_rp. Procaspase 3.1 was subcloned into pTZP01 using the restriction sites AscI /BsmBI. Positive clones were screened by PCR and plasmid DNA was isolated. The cloned target sequence of the final construct was verified via sequencing. The pHIL-D2_Casp3.1 construct will be expressed intracellular as Procaspase 3.1 with an N-terminal 6xHis-tag. The following cloning strategy was applied: Procaspase 3.1 was PCR-amplified from plasmid MRZ_Casp3.1 with the following primers:

1369_Casp3.1_pHILD2_fp

AACAATTGTCTGCCATCATGCATCATCATCATCATAACAGCTACAAGATGGACT
ACC (SEQ ID NO: 15)

1369_Casp3.1_pHILD2_rp AACAATTGTTATTAGAGACCGTGGTAGAAGTACAGCTC
(SEQ ID NO: 16)

[0072] Procaspase 3.1 was subcloned into pHILD2 using the restriction sites MfeI / EcoRI. The insertion can take place in two different orientations (cw and ccw). The desired orientation (1369_pHILD2_Casp3.1_cw) is identified by restriction analysis and sequencing. Positive clones

were screened by PCR and plasmid DNA was isolated. The cloned target sequence of the final construct was verified via sequencing.

[0073] **Example 3:** Expression in *E. coli* of pTZE02 / Casp3.1

[0074] The construct is a pET24d based vector derivative, encoding for Procaspase 3.1 with a Cterminal Streptag II. The expected molecular weight of Casp3.1 is 30,4 KDa, with an estimated pI of 8,5. For analyzing the expression pTZE02 / Casp3.1 (KanR) was transformed into the following *E. coli* strains:

BL21 (DE3)

BL21 (DE3) / pGroEL ES (CamR)

Rosetta (DE3) / pRARE2 (CamR)

Rosetta (DE3) / pLys (CamR)

[0075] Cells were grown at 37°C in LB medium supplemented with 50 µg/ml kanamycin (and 30 µg/ml chloramphenicol for the respective strains) until an OD₆₀₀ of 0.4 was reached. Each culture was shifted to 30°C and grown until an OD₆₀₀ of 0.5 was reached. Cultures were induced with 0.2 mM IPTG and grown for another 22 hours at 30°C. After 0, 1, 4 and 22 hours of induction samples were taken and treated with Bug buster HT solution (Novagen) to break the cells and separate soluble and insoluble protein fractions. Samples were analysed via SDS-PAGE analysis on 12% Gels (Fig. 2 and 3).

[0076] **Example 4:** Expression in *E. coli* of pTZE44 / Casp3.1

[0077] The construct consists of ssMBP (Maltose binding protein with signal sequence for periplasmatic expression) fused to Procaspase 3.1. The final construct encodes for a periplasmatic expressed MBP-Procaspase 3.1-fusionprotein with a C-terminal Streptag II. The MBP fusion partner can be cleaved from the Procaspase 3.1 part using the serin protease factorXa yielding native, Strep-tagged Procaspase 3.1. The expected molecular weight of MBP-Casp3.-fusion protein (MBP-Signal sequence cleaved off) is 74 KDa, with an estimated pI of 6,9. For analyzing the expression pTZE44 / Casp3.1 (AmpR) was transformed into the following *E. coli* strains:

BL21 (DE3)

BL21 (DE3) / pGroEL ES (CamR)

Rosetta (DE3) / pRARE2 (CamR)

Rosetta (DE3) / pLys (CamR)

[0078] Cells were grown at 37°C in LB medium supplemented with 200 µg/ml ampicillin (and 30 µg/ml chloramphenicol for the respective strains) until an OD₆₀₀ of 0.4 was reached. Each culture was shifted to 30°C and grown until an OD₆₀₀ of 0.5 was reached. Cultures were induced with 0.2 mM IPTG and grown for another 22 hours at 30°C. After 0, 1, 4 and 22 hours of induction samples were taken and treated with Bug buster HT solution (Novagen) to break the cells and separate soluble and insoluble protein fractions. Samples were analysed via SDS-PAGE analysis on 12% Gels (and via Western-blot with anti-Strep-tag antibody); see Fig. 4 and 5. The western-blot analysis revealed the presence of a protein running slightly below the 70 kDa molecular weight marker band in the insoluble protein fraction of the Rosetta(DE3) / pRARE2 and the Rosetta(DE3) / pLys expression after 4-22 hours of induction. A weak protein band detected with the Strep-Tag antibody is also visible in the insoluble protein fraction of the BL21(DE3) / pGroESEL expression after 4-22 hours of induction. Whether this bands correspond to MBP-Casp3.-fusion protein could not be solved.

[0079] To optimize the previously tested expression conditions of the pTZE02 / Casp 3.1 construct, four further test-expressions were performed. pTZE02 / Casp3.1 (KanR) was transformed into the following E. coli strains:

Rosetta (DE3) / pRARE2 (CamR)

Rosetta (DE3) / pLys (CamR)

[0080] Cells were grown at 37°C in LB medium supplemented with 50 µg/ml kanamycin and 30 µg/ml chloramphenicol until an OD₆₀₀ of 0.4 was reached. Each culture was split in two equal parts. One half of each culture was shifted to 30°C, the other half to 20°C and grown until an OD₆₀₀ of 0.5 was reached. Cultures were induced with 0.2 mM IPTG and grown for another 24 hours at the respective temperature. After 0, 1, 4, 6, 8 and 24 hours of induction samples were taken and treated with Bug buster HT solution (Novagen) to break the cells and separate soluble and insoluble protein fractions. Samples were analysed via SDS-PAGE analysis on 12% Gels (and via Western-blot with anti-Strep-tag antibody); see Fig. 6 to 9. Western blot analysis was performed to clearly relate bands in the Coomassie stained gel to the Casp 3.1 target and estimate

the amount of soluble compared to insoluble target. To clearly relate bands in the Coomassie stained gel to the Casp 3.1 target and estimate the amount of soluble compared to insoluble target, western blot analysis was performed. The western-blot analysis revealed the presence of a protein running between the 25 and the 35 kDa molecular weight marker band in the soluble and the insoluble protein fraction of all tested expression conditions. The detected protein band in the Rosetta(DE3) / pRARE2 expression at 20°C (induction for 6-8 hours) is corresponding with the expected molecular weight (30,4 kDa) of the translated Casp3.1 protein and revealed, that at least 50% of the target should be present in a soluble form. Again western-blot analysis revealed the presence of a protein running between the 25 and the 35 kDa molecular weight marker band in the soluble and the insoluble protein fraction of all tested expression conditions. The detected protein band in the Rosetta(DE3) / pLys expression at 20°C (induction for 6-8 hours) is corresponding with the expected molecular weight (30,4 kDa) of the translated Casp3.1 protein and revealed, that at least 50% of the target should be present in a soluble form. The best expression result was achieved in Rosetta (DE3) / pRARE2 at 20°C and an induction time of 8 hours.

[0081] **Example 5:** Expression in *P. pastoris* of pTZP01 / Casp3.1 and pHil-D2 / Casp3.1

[0082] This construct is a pPICZalphaA based vector derivative carrying a secretion signal (α -factor). The final construct is secreted as Procaspase 3.1 with a C-terminal Streptag II. The expected molecular weight of secreted Casp3.1 protein (KEX2 and STE13 coded cleavage site between Arginin and Glutamin at the following recognition site: Glu-Lys-Argcleavage site-Glu-Ala-Glu-Ala-Caspase3.1) is 30,4 KDa, with an estimated pI of 8.48. For analyzing the expression pTZP01 / Casp3.1 (ZeocinR) was linearized with Sall and transformed into the following *P. pastoris* strains:

X33

KM71

GS115

[0083] Recombination into the AOX locus was verified by screen-PCR. Recombinant cells were grown at 28°C in YPD medium for three days (pre-cultures, final OD600 of 16 was reached in the case of KM71 and GS115, OD600 of 18 was reached in the case of X33). Each pre-culture was inoculated in MGY-medium (please refer to the provided Invitrogen manual, supplemented

with 0.04% Histidine for KM71 and GS115) and grown until an OD600 of 5 was reached. Cultures were induced with 0.5 % (final concentration) methanol and grown for another 72 hours at 28°C. After 0, 24, 48 and 72 hours of induction samples were taken. Glass bead lysis was performed to break the cells and separate soluble and insoluble protein fractions. Samples were analysed via SDS-PAGE analysis on 12% Gels (Fig. 10 and 11). To clearly identify Casp 3.1 protein bands in the Coomassie stained gel and estimate the amount of soluble compared to insoluble target, western blot analysis with anti-Strep-tag antibody was performed. No protein band running at the expected molecular weight of 30,4 KDa was detectable after the induction with methanol in the western-blot analysis. Nearly no signals were detected in the secreted (soluble) fractions even when 1/6 of an OD600 of 10 was loaded on the gels. Whether this is due to bad or no secretion of the target or due to general bad expression remains unclear.

[0084] The final construct pHil-D2 / Casp3.1 is expressed intracellularly as Procaspase 3.1 with an N-terminal 6xHis-tag. The expected molecular weight of His-Casp3.1 protein is 30 KDa, with an estimated pI of 8.49. For analyzing the expression pHIL-D2 / Casp3.1 (AmpR) was linearized with Sall and transformed into the following *P. pastoris* strains:

KM71

GS115

[0085] Recombination into the HIS4 locus was verified by screen-PCR. Recombinant cells were grown at 28°C in SDC medium without histidine for three days (precultures, final OD600 of 4,52 was reached in the case of KM71 and OD600 of 3,29 was reached in the case of GS115). Each pre-culture was inoculated in SDC-medium (without histidine) and grown until an OD600 of 2,5 was reached. Cultures were induced with 0.5 % (final concentration) methanol and grown for another 72 hours at 28°C. After 0, 24, 48 and 72 hours of induction samples were taken and treated with glass beads to break the cells. Samples were analysed via SDS-PAGE analysis on 12% Gels (and via Western-blot with anti-Strep-tag antibody); see Fig. 12. A protein band running at the expected molecular weight of 30 KDa was detectable after the induction with methanol in the western-blot analysis. The intensity of the detected protein band seems to decrease the longer the induction lasts. This could either be due to the reduced stability of the produced target over time or due to a decreasing expression over time.

[0086] **Example 6:** Activation of Casp3.1 by BoNT/A

[0087] Purified Casp3.1 has been incubated with active BoNT/A for 2 hours at 37°C. The cleavage products obtained by the reaction have been separated by SDS PAGE and further analyzed by Western blotting. The results are shown in Fig. 13. Although there is also some autocatalytic activation of Casp3.1, a dose dependent BoNT/A induced activation of Casp3.1 has also been observed.

CLAIMS

1. A polypeptide exhibiting caspase activity comprising a large subunit and a small subunit wherein said caspase further comprises a neurotoxin cleavage site which upon cleavage activates the caspase activity, wherein said neurotoxin cleavage site is a Clostridium botulinum or Clostridium tetani cleavage site which is located between the C-terminal proximal region of the large subunit and the N-terminal proximal region of the small subunit, and wherein
 - (i) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids C170 to D175, L168 to E173, Q161 to D175, or Q161 to E173 of the large subunit of caspase 3 (SEQ ID NO: 7) and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S176 to V190 or S176 to C184 of the small subunit of caspase 3 (SEQ ID NO: 7),
 - (ii) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids V174 to D179, H172 to V177, Q165 to D179, or Q165 to V177 of the large subunit of caspase 6 (SEQ ID NO: 12) and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S180 to A194 or S180 to V188 of the small subunit of caspase 6 (SEQ ID NO: 12),
 - (iii) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids D193 to D198, L191 to Q196, Q184 to D198, or Q184 to Q196 of the large subunit of caspase 7 (SEQ ID NO: 11) and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S199 to V213 or S199 to R207 of the small subunit of caspase 7 (SEQ ID NO: 11),
 - (iv) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids K369 to D374, Y367 to E372, Q360 to D374, or Q360 to E372 of the large subunit of caspase 8 (SEQ ID NO: 8) and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids S375 to D389 or S375 to T383 of the small subunit of caspase 8 (SEQ ID NO: 8),
 - (v) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids P367 to D372, I365 to E370, Q358 to D372, or Q358 to E370 of the large subunit of caspase 10 (SEQ ID NO: 9) and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids A373 to A386 or A373 to Q380 of the small subunit of caspase 10 (SEQ ID NO: 9),
 - (vi) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids H310 to D315, K308 to E313, Q301 to D315, or Q301 to E313 of the large subunit of caspase 9 (SEQ ID NO: 6) and said N-terminal proximal region of the small subunit consists of the amino acids corresponding to amino acids A316 to T330 or A316 to I324 of the small subunit of caspase 9 (SEQ ID NO: 6), or
 - (vii) said C-terminal proximal region of the large subunit consists of the amino acids corresponding to amino acids R311 to D316, T309 to Q314, Q302 to D316, or Q302 to Q314 of the large subunit of caspase 2 (SEQ ID NO: 10) and said N-terminal proximal region of the

can_dms: \116223538\1

small subunit consists of the amino acids corresponding to amino acids G317 to T331 or G317 to K325 of the small subunit of caspase 2 (SEQ ID NO: 10).

2. The polypeptide of claim 1, wherein said polypeptide further comprises a prodomain.
3. The polypeptide of claim 1 or 2, wherein said neurotoxin cleavage site is a cleavage site recognized and cleaved by the BoNT/A protease.
4. The polypeptide of claim 3, wherein said cleavage site is shown in any one of SEQ ID NO: 1 to 5.
5. The polypeptide of claim 1 or 2, wherein said neurotoxin cleavage site is a cleavage site recognized and cleaved by the BoNT/B, BoNT/C1, BoNT/D, BoNT/E, BoNT/F, BoNT/G or TeNT protease.
6. A polynucleotide encoding a polypeptide as defined in any one of claims 1 to 5.
7. A vector comprising the polynucleotide of claim 6.
8. A host cell comprising the polypeptide of any one of claims 1 to 5, the polynucleotide of claim 6 or the vector of claim 7.
9. A method for determining neurotoxin activity in a sample comprising the steps of:
 - (a) contacting the polypeptide of any one of claims 1 to 5 or the host cell of claim 8 with a sample suspected to comprise neurotoxin activity; and
 - (b) measuring caspase activity of the polypeptide, whereby neurotoxin activity in the sample is determined.
10. The method of claim 9, wherein said caspase activity is measured by cleavage of at least one substrate of the polypeptide.
11. The method of claim 10, wherein said substrate is at least one effector caspase.
12. Use of the polypeptide of any one of claims 1 to 5, the polynucleotide of claim 6, the vector of claim 7 or the host cell of claim 8 for determining neurotoxin activity in a sample.
13. A kit for determining neurotoxin activity comprising at least one of the polypeptide of any one of claims 1 to 5, the polynucleotide of claim 6, the vector of claim 7 and the host cell of claim 8; and

a calibration standard solution including at least one of a neurotoxin polypeptide and a means for measuring caspase activity.

Modified Human Caspase-3

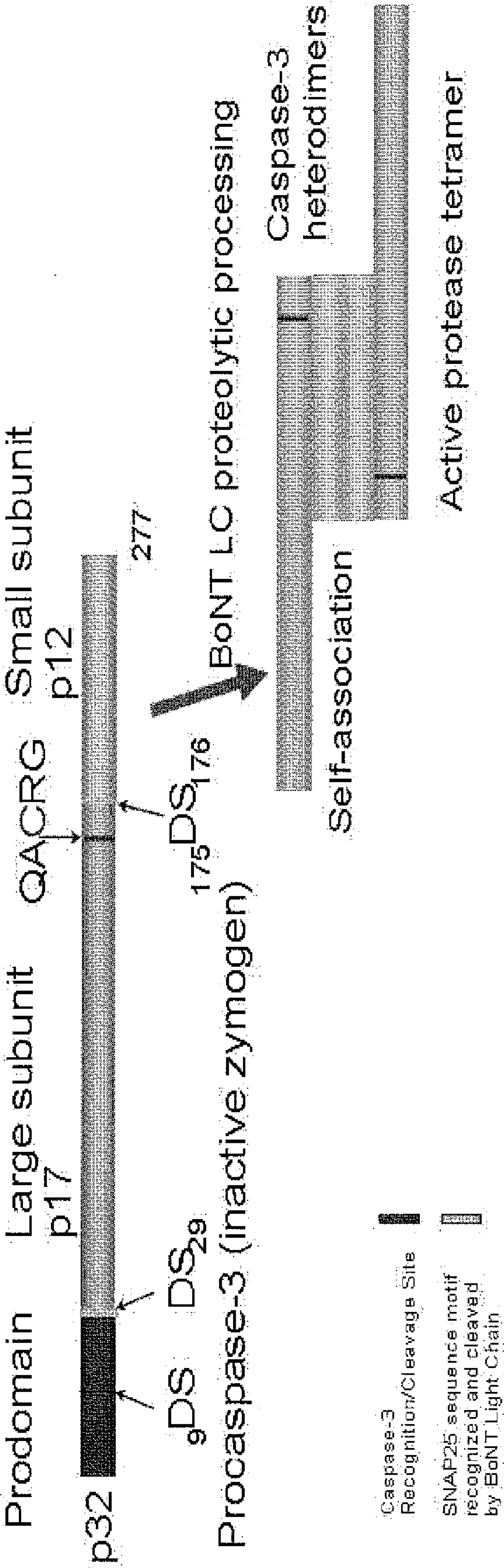


Fig. 1

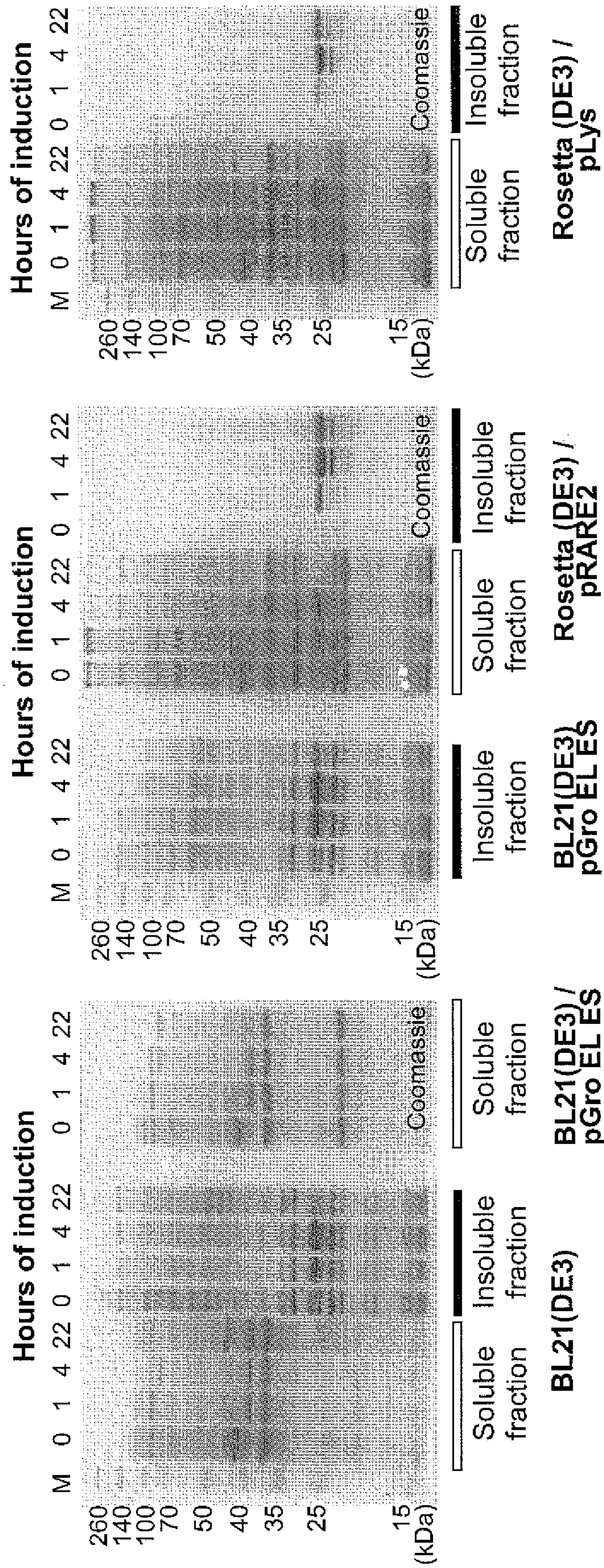


Fig. 2

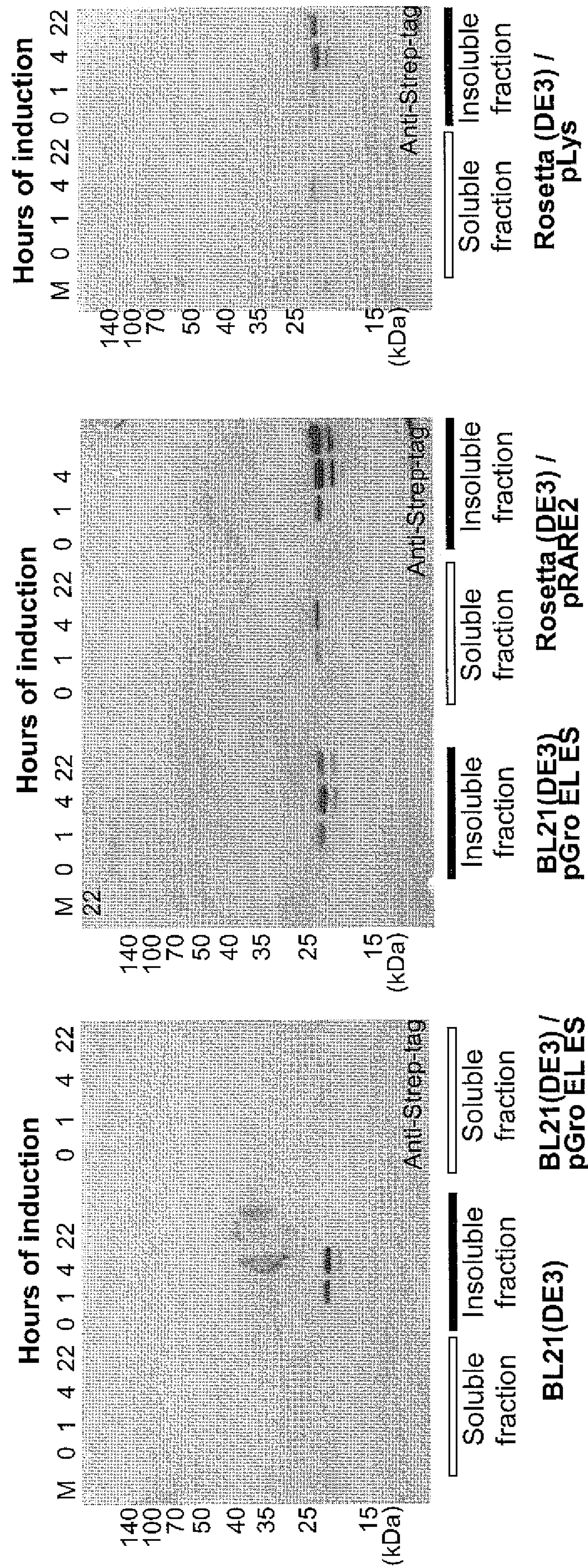


Fig. 3

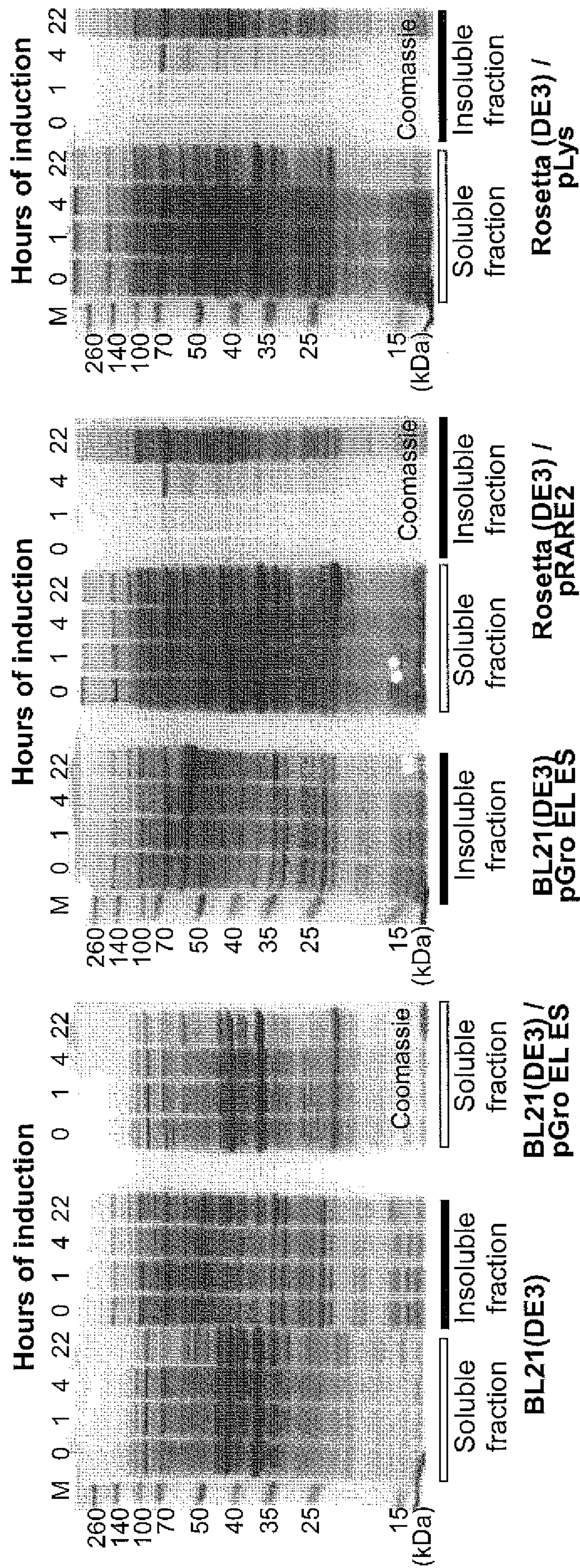


Fig. 4

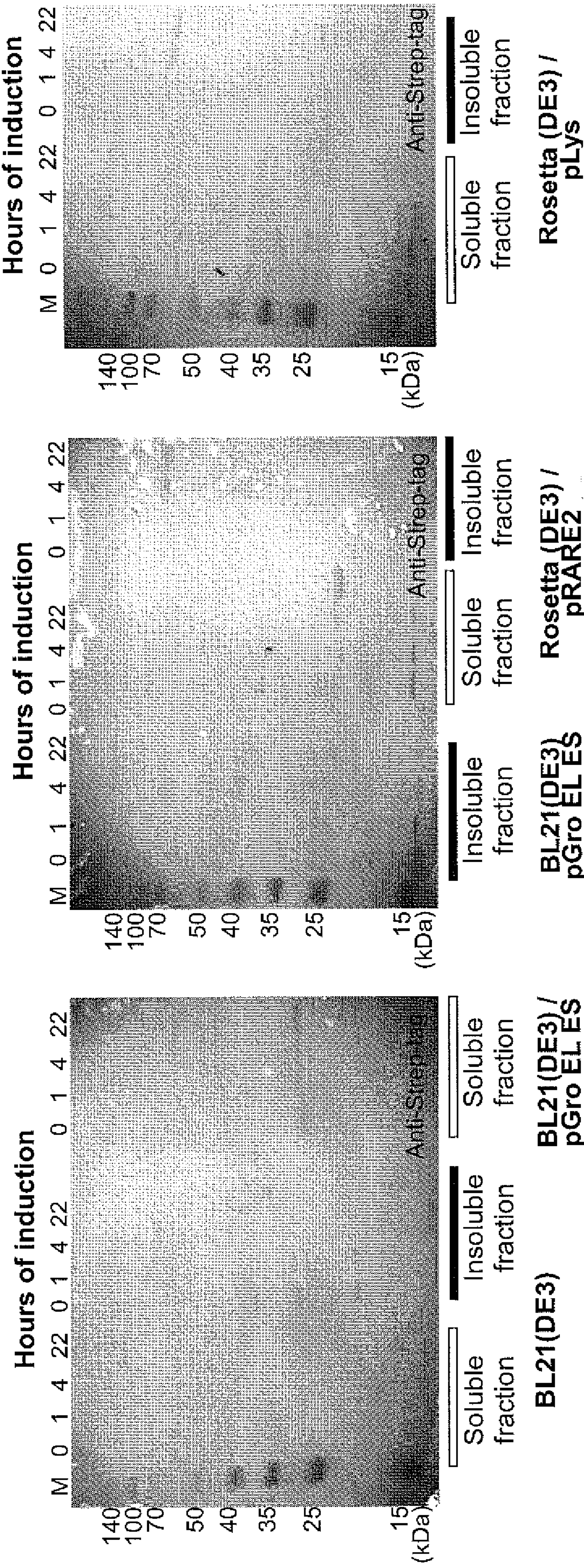


Fig. 5

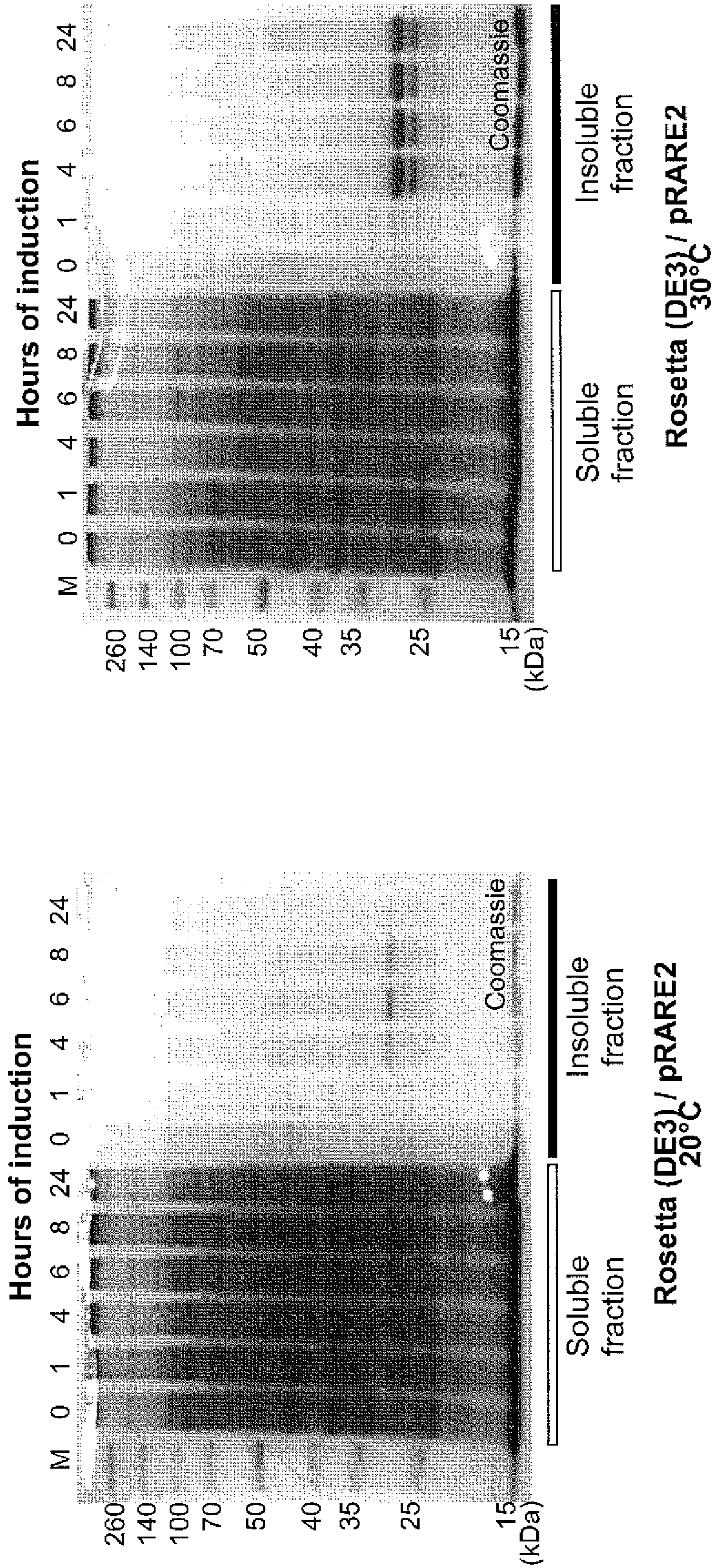


Fig. 6

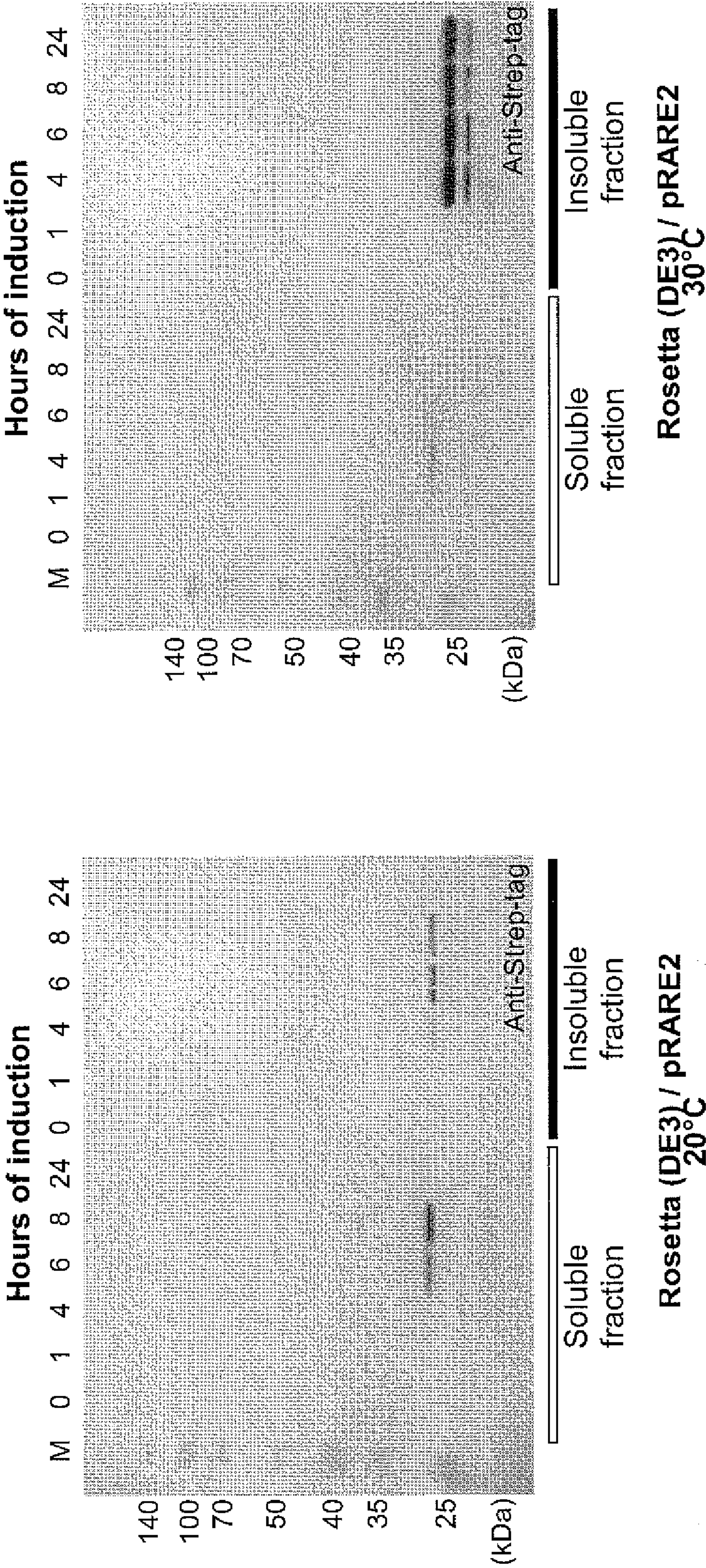


Fig. 7

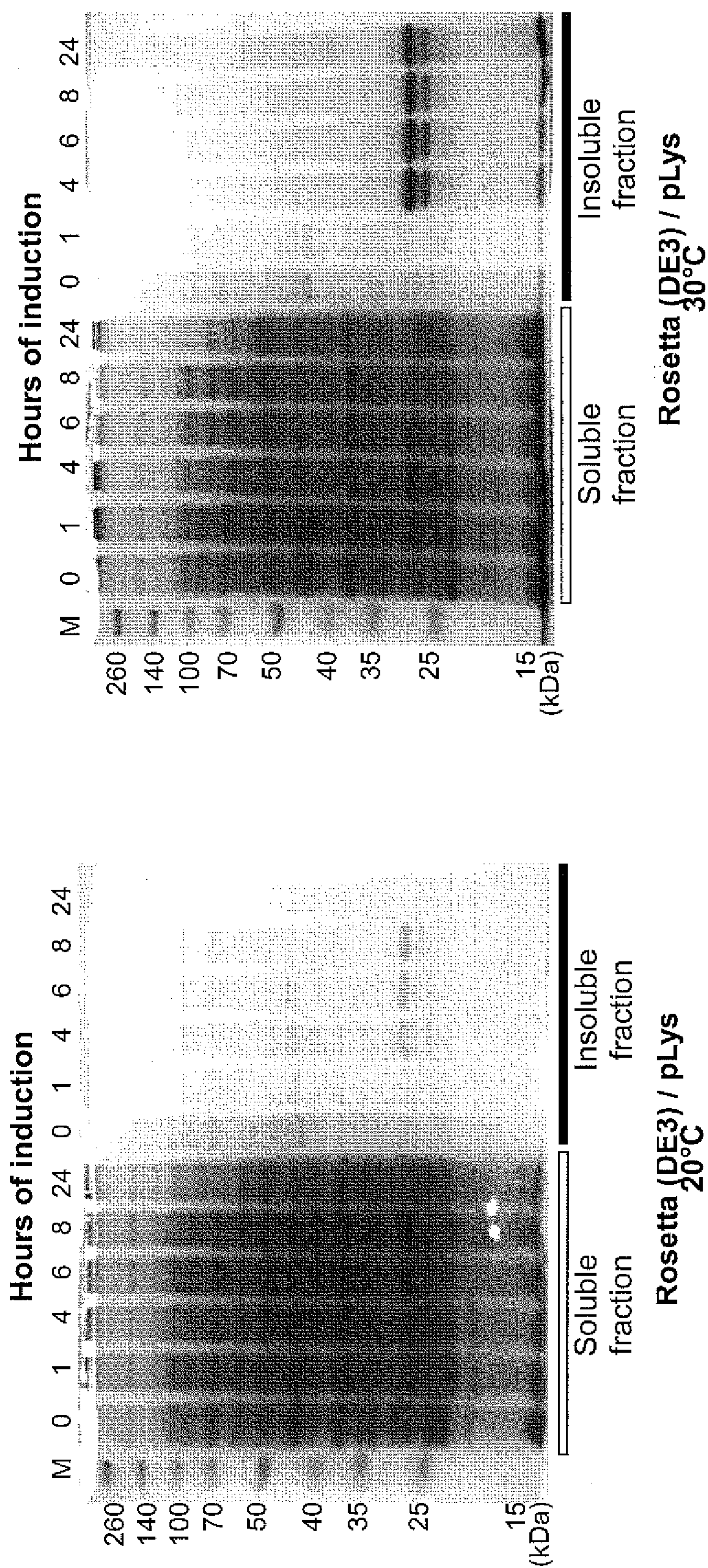


Fig. 8

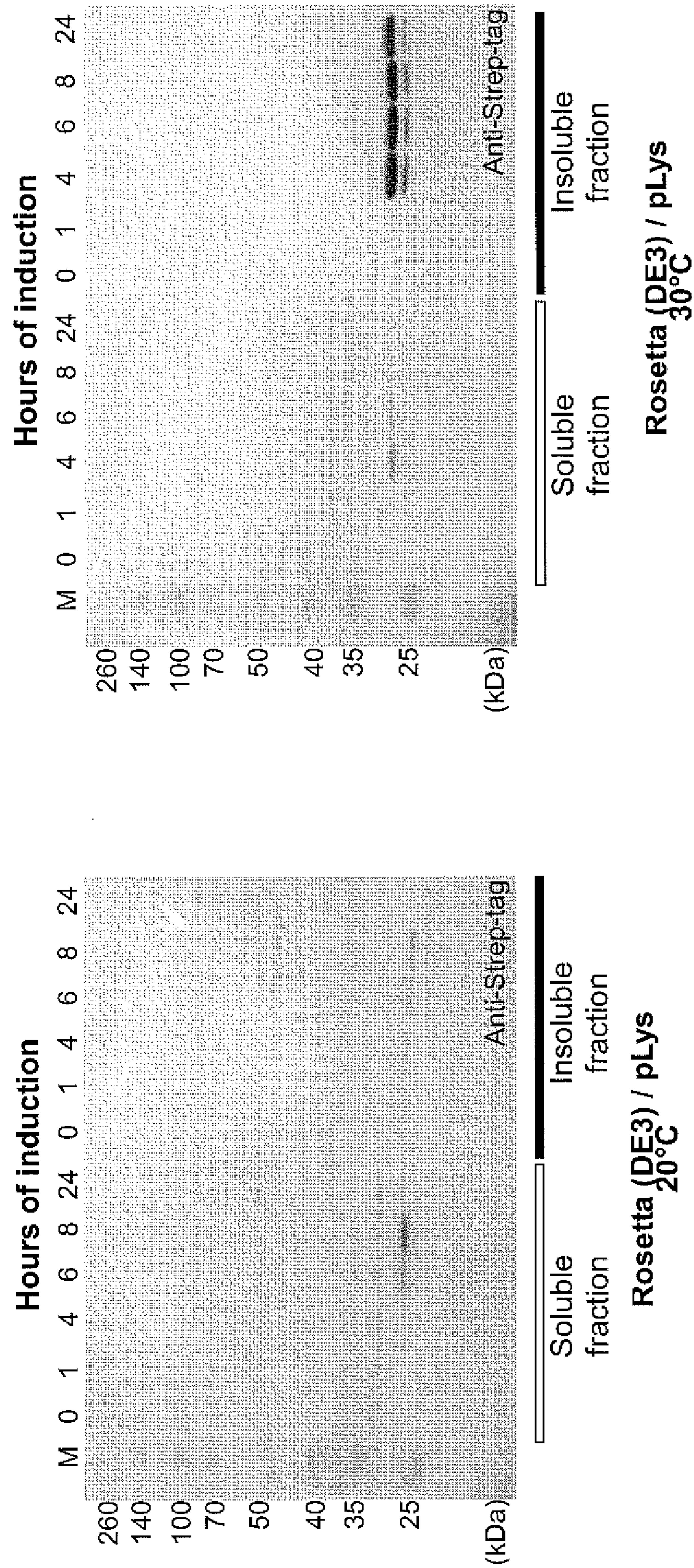


Fig. 9

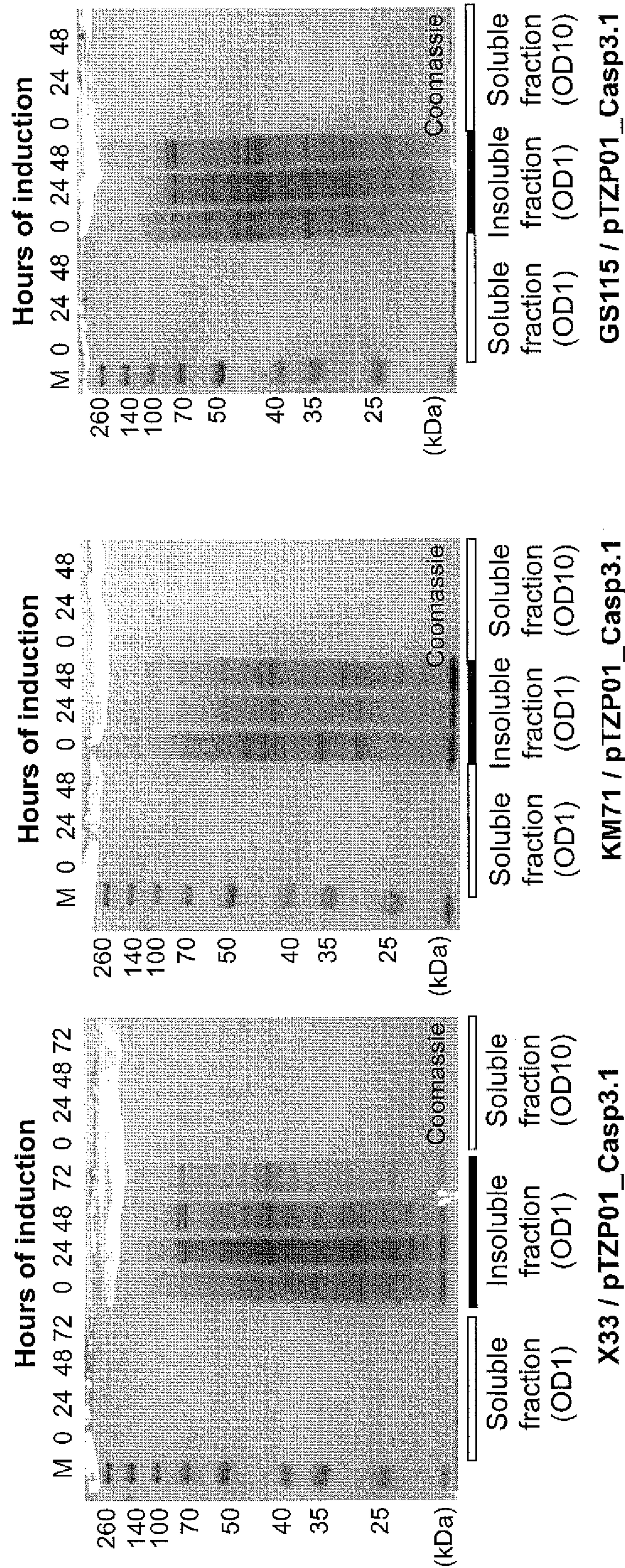


Fig. 10

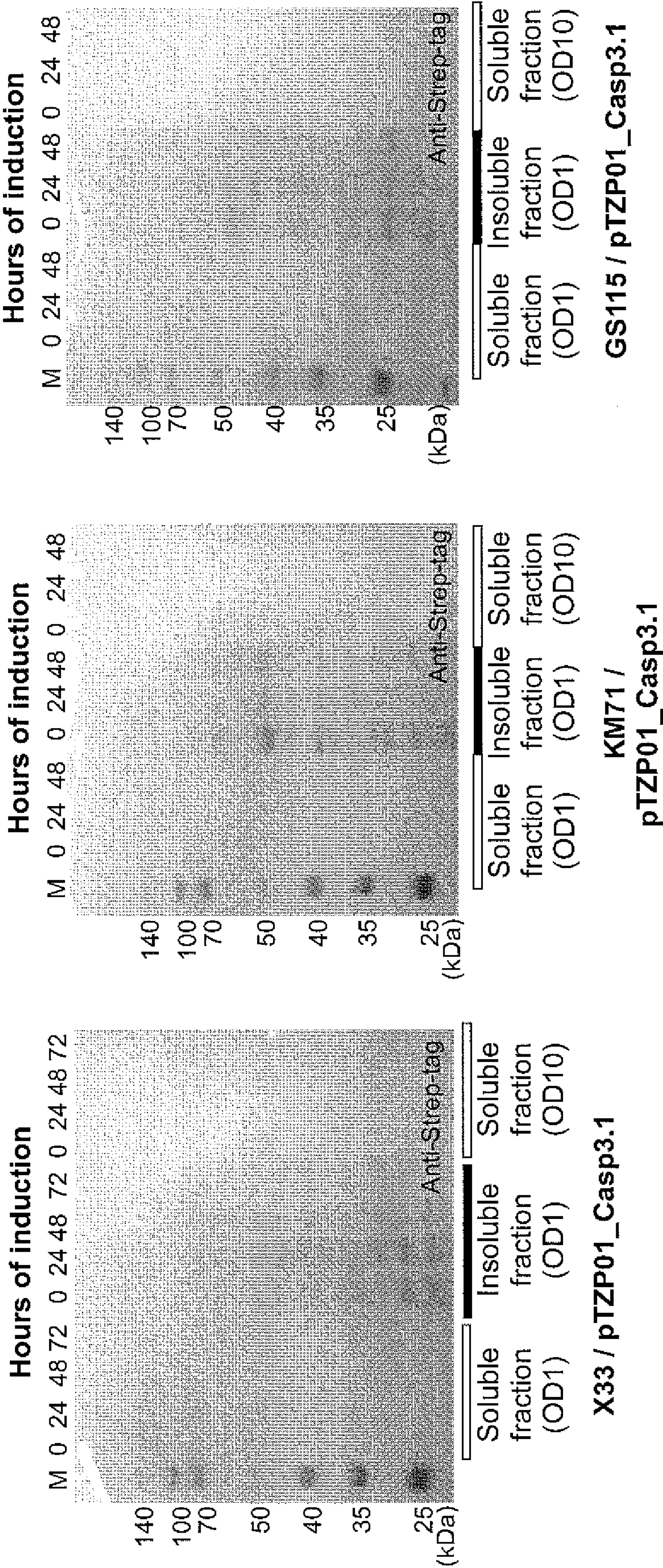


Fig. 11

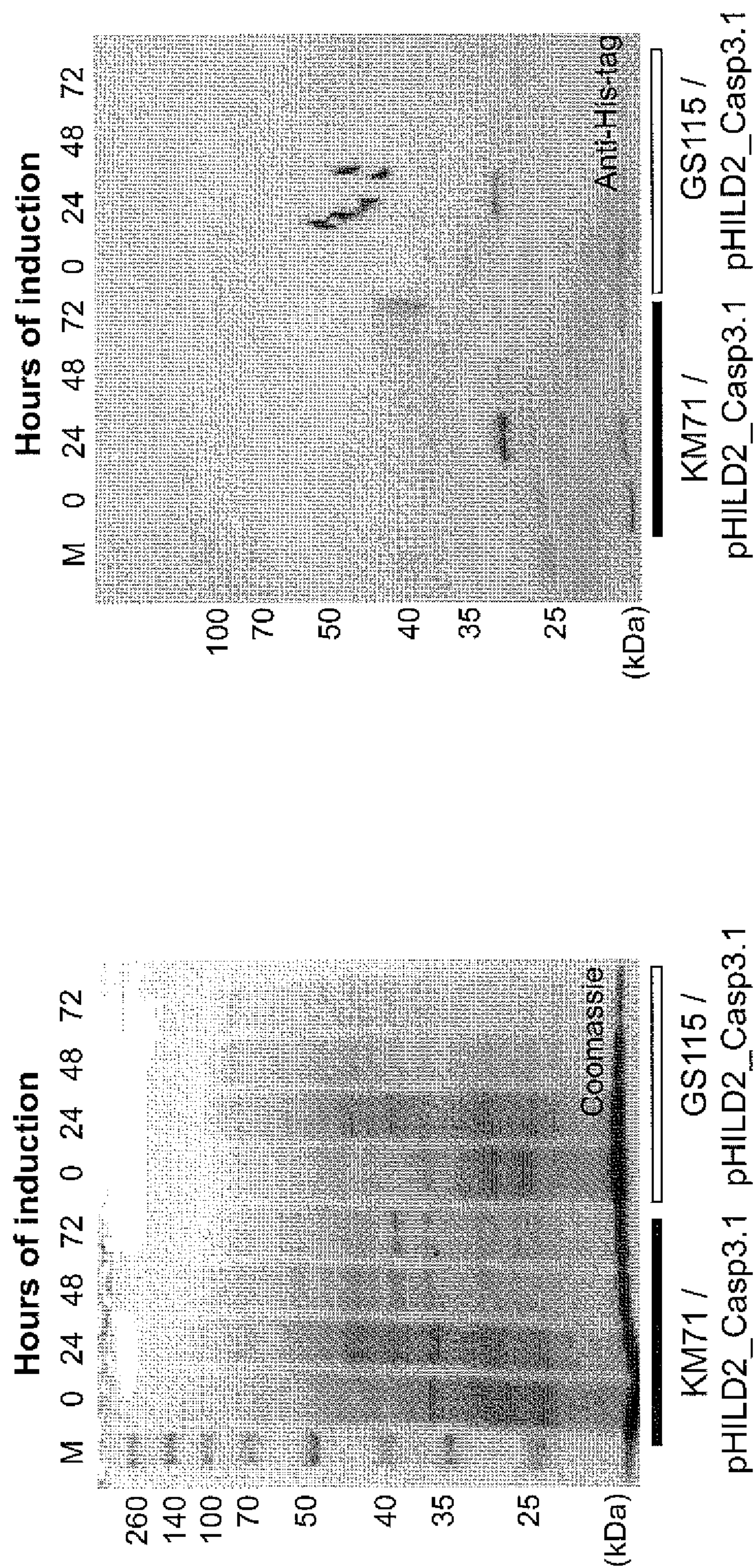


Fig. 12

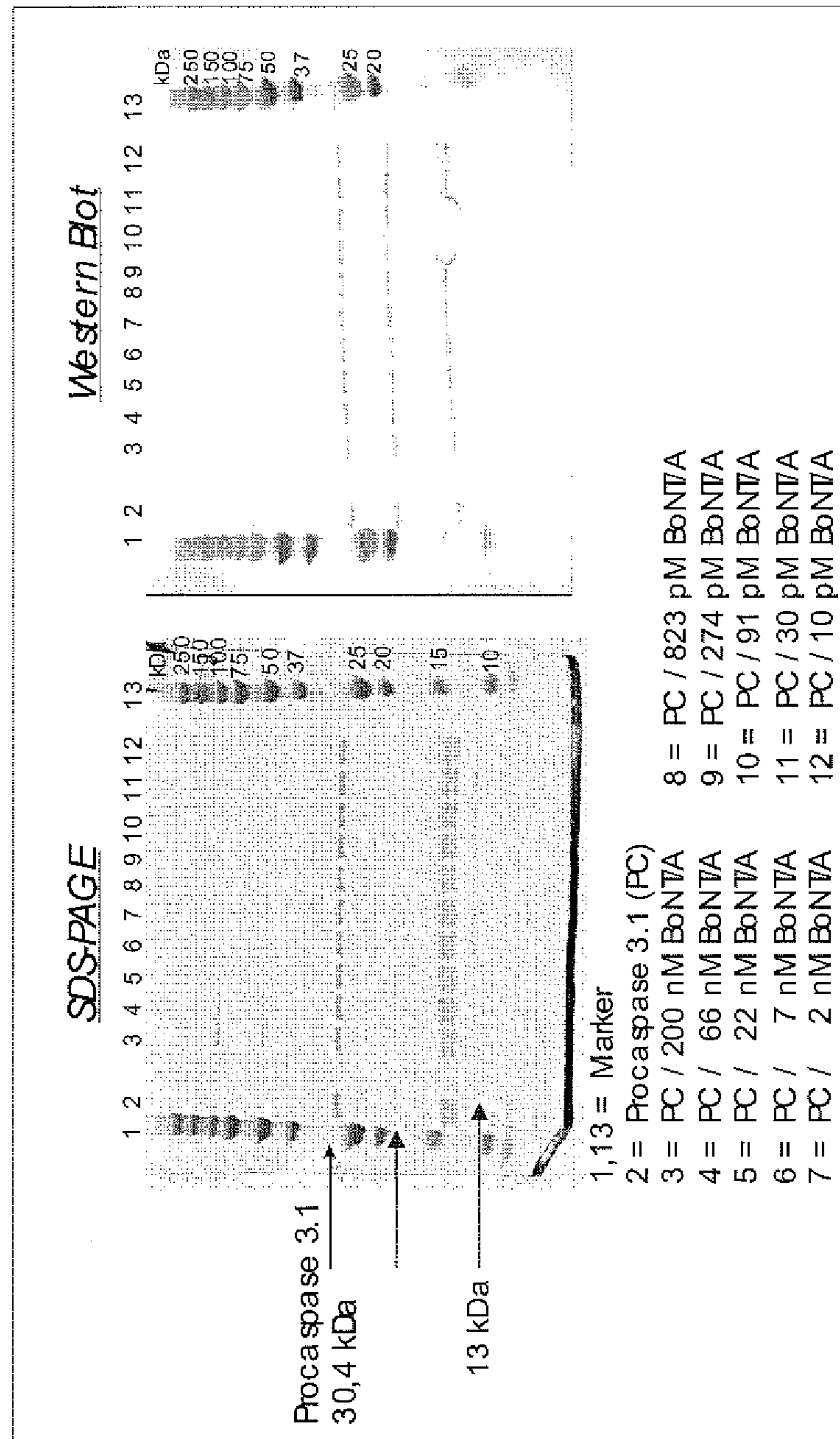


Fig. 13