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(54) **Titre : PROTEINE RECOMBINANTE RENFERMANT DE L'ERYTHROPOIETINE ET DES FRAGMENTS GLYCOSYLATES**
(54) **Title: RECOMBINANT PROTEIN COMPRISING ERYTHROPOIETIN AND GLYCOSYLATED FRAGMENTS**

(57) **Abrégé/Abstract:**

A recombinant protein is provided. The recombinant protein of the invention comprises an erythropoietin and a highly glycosylated peptide, and has a longer half-life. Further, the recombinant protein of the invention may also comprise a carboxyl-terminal peptide of human chorionic gonadotropin and a carboxyl-terminal peptide of thrombopoietin.

ABSTRACT

A recombinant protein is provided. The recombinant protein of the invention comprises an erythropoietin and a highly glycosylated peptide, and has a longer half-life. Further, the recombinant protein of the invention may also comprise a carboxyl-terminal peptide of human chorionic gonadotropin and a carboxyl-terminal peptide of thrombopoietin.

RECOMBINANT PROTEIN COMPRISING ERYTHROPOIETIN AND GLYCOSYLATED FRAGMENTS

FIELD OF THE INVENTION

The present invention relates to a recombinant protein, and in particular relates to a highly glycosylated erythropoietin (EPO) with a longer half-life.

BACKGROUND OF THE INVENTION

Erythropoiesis (EPO) is a glycoprotein hormone, or a cytokine of red blood cell precursors in the bone marrow. In human, erythropoiesis is involved in the process of red blood cells, and modulation of hormone. Simultaneously, erythropoiesis also has other biological functions. For example, erythropoiesis is involved in the process of wound healing when nervy damage is present.

Erythropoiesis is the production of red blood cells, which occurs to offset cell destruction. Erythropoiesis is a controlled physiological mechanism that enables sufficient red blood cells to be available for proper tissue oxygenation. Naturally occurring human erythropoietin (hEPO) is produced in the kidney and is the humoral plasma factor which stimulates red blood cell production (Carnot, P and Deflandre, C (1906) C. R. Acad. Sci. 143: 432; Erslev, A J (1953 Blood 8: 349; Reissmann, K R (1950) Blood 5: 372; Jacobson, L O, Goldwasser, E, Freid, W and Plzak, L F (1957) Nature 179: 6331-4). EPO stimulates the division and differentiation of committed erythroid progenitors in the bone marrow and exerts its biological activity by binding to receptors on erythroid precursors (Krantz, B S (1991) Blood 77: 419).

Erythropoietin has been manufactured biosynthetically using recombinant DNA technology (Egrie, J C, Strickland, T W, Lane, J et al. (1986) Immunobiol. 72: 213-224) and is the product of a cloned human EPO gene inserted into and expressed in the ovarian tissue cells of the chinese hamster (CHO cells). The molecular weight of the polypeptide chain of EPO without the sugar moieties is 18,236 Da. In the intact EPO molecule, approximately 40% of the molecular weight are accounted for by the carbohydrate groups that glycosylate the protein at glycosylation sites on the protein (Sasaki, H, Bothner, B, Dell, A and Fukuda, M (1987) J. Biol. Chem. 262: 12059).

Because human erythropoietin is essential in red blood cell formation, the hormone is useful in the treatment of blood disorders characterized by low or defective red blood cell production. Clinically, EPO is used in the treatment of anemia in chronic renal failure

patients (CRF) (Eschbach, J W, Egri, J C, Downing, M R et al. (1987) NEJM 316: 73-78; Eschbach, J W, Abdulhadi, M H, Browne, J K et al. (1989) Ann. Intern. Med. 111: 992; Egrie, J C, Eschbach, J W, McGuire, T, Adamson, J W (1988) Kidney Intl. 33: 262; Lim, V S, Degowin, R L, Zavala, D et al. (1989) Ann. Intern. Med. 110: 108-114) and in AIDS and cancer patients undergoing chemotherapy (Danna, R P, Rudnick, S A, Abels, R I In: M B, Garnick, ed. Erythropoietin in Clinical Applications—An International Perspective. New York, N.Y.: Marcel Dekker; 1990: p. 301-324). However, the bioavailability of EPO protein therapeutic is limited by its short plasma half-life and protease degradation such that it is hard to attain good clinical potency .

SUMMARY OF THE INVENTION

The invention provides a highly glycosylated erythropoietin (EPO) with a long half-life.

In order to achieve the goal, the invention provides a recombinant protein comprising an erythropoietin and a highly glycosylated peptide.

The invention further provides a nucleotide encoding the recombinant protein.

The invention also provides a cell which is transfected with the nucleotide to express the recombinant protein.

The invention further provides a composition, comprising the recombinant protein and a pharmaceutically acceptable carrier or adjuvant.

In order to achieve the purpose stated above, as well as other purposes, the characteristics and advantages of the present invention can be more apparent and understandable, and preferred embodiments are exemplified in the following with accompanying drawings to aid in detailed interpretation.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the plasmid construction of EPO-NNCT, NNCT-EPO, EPO-N1N2, N1N2-EPO, EPO-N1, and EPO-N2 according to the embodiments of the present invention.

Figure 2 illustrates the comparison of activity levels between EPO-NNCT of the present invention and commercial Eprex®.

Figure 3 illustrates the comparison of pharmacokinetic properties (PK) between EPO-NNCT of the present invention and commercial Eprex® (intravenous injection).

Figure 4 illustrates the comparison of pharmacokinetic properties (PK) between EPO-NNCT of the present invention and commercial Eprex® (subcutaneous injection).

Figure 5 illustrates the comparison of pharmacokinetic properties (PK) between EPO-N1N2, N1N2-EPO, NNCT-EPO of the present invention and commercial Eprex® (subcutaneous injection).

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides a recombinant erythropoietin with a long half-life and a manufacture method thereof.

In one embodiment, the present invention provides a recombinant protein comprising an erythropoietin and a highly glycosylated peptide.

As used herein, the phrase “erythropoietin (EPO)” used herein includes EPO of every origin, especially human or animal EPO. The term used herein encompasses not only the naturally occurring, that is wild-type forms of EPO, but also its derivatives, analogs, modifications, mutants or others, as long as they show the biological effects of wild-type erythropoietin.

Any protein having the activity of EPO, such as muteins or otherwise modified proteins, is also encompassed. Recombinant EPO may be prepared via expression in CHO, BHK, COS, HeLa or PER.C6 cell lines or other appropriate cell lines, by recombinant DNA technology and the related content can be referred to U.S. Pat. Nos. 5,733,761, 5,641,670, 5,733,746, 5,994,122, 5,733,761, 5,641,670, 5,981,214 and 5,272,071. Its preparation and therapeutic application can be referred to U.S. Pat. Nos. 5,547,933 and 5,621,080, , Huang, S. L., Proc. Natl. Acad. Sci. USA (1984) 2708-2712, as well as Lai, P. H. et al., J. Biol. Chem. 261 (1986) 3116-3121, an Sasaki, H. et al., J. Biol. Chem. 262 (1987) 12059-12076. The preferred EPO species are human EPO species.

As used herein, the phrase “highly glycosylated peptide” refers to a polypeptide having about 10 to 30 amino acid residues with at least one glycoside. The highly glycosylated peptide of the present invention includes one or more N- or O-linked glycosylation stie(s) for producing one or more glycan(s). For example, a sequence of SEQ ID NO: 1 and/or 2, or a sequence having at least 60%, 65%, 70%, and 80% sequence identity to SEQ ID NO: 1 or 2, preferably, 90%, 95%, or 99% sequence identity.

The highly glycosylated peptide is fused with an EPO to form the recombinant protein of the present invention. The highly glycosylated peptide can be located on the N-terminal

end (N-ter) or carboxy-terminal end (C-ter) of the EPO, and the number of the highly glycosylated peptide is not limited. For example, one or more the same or different highly glycosylated peptide (s) can be attached to N-terminal end and/or C-terminal end of the EPO. The recombinant protein containing the highly glycosylated peptide has a longer half-life and higher activity. In one embodiment, the highly glycosylated peptide (SEQ ID NO: 1 and/or 2) can be located on the N-ter or C-ter of EPO, as shown in **Fig. 1**.

The highly glycosylated peptide includes, but is not limited to, SEQ ID NO: 1 and/or 2. One or more the same or different highly glycosylated peptide(s) can be attached to the C-ter of EPO. For example, SEQ ID NO: 1 or 2 is attached to the C-ter of EPO; or two or more SEQ ID NO: 1 or 2 are attached to the C-ter of EPO; or SEQ ID NO: 1 and 2 are attached to the C-ter of EPO, sequentially; or SEQ ID NO: 2 and 1 are attached to the C-ter of EPO, sequentially. In another embodiment, SEQ ID NO: 1 and 2 are attached to the C-ter of EPO, sequentially.

The recombinant protein of the present invention further comprises a carboxy terminal peptide of human chorionic gonadotropin (hCG).

As used herein, the phrase “carboxy terminal peptide of hCG (hereinafter referred to as CTP)” refers to an amino acid sequence found at the carboxy terminus of human chorionic gonadotropin .beta. subunit which extends from amino acid 112-118 to residue 145 at the C-terminus or to a portion, or a variant or analog thereof, which has equivalent biological activity. The CTP sequence peptide is 28, 29, 30, 31, 32, 33 or 34 amino acids long and commences at position 112, 113, 114, 115, 116, 117, or 118 of the hCG amino acid sequence.

The CTP of the present invention includes, but is not limited to, SEQ ID NO: 3, or a sequence having at least 65%, 70%, 80%, 90% sequence identity to SEQ ID NO: 3, preferably at least 95% sequence identity.

The CTP of the invention may be attached to EPO (at the N-ter or C-ter) and/or the highly glycosylated peptide (at the N-ter or C-ter). The amount of the CTP is not limited. For example, one or more the same or different CTP of hCG can be attached to the N-ter of EPO or C-ter of the highly glycosylated peptide(s) of the invention.

The CTP of the present invention may acts as a protectant against degradation of proteins or peptides. In the present application, the CTP of hCG can extends circulatory half-life of recombinant proteins, and enhances the potency of recombinant proteins.

The invention further comprises a carboxy terminal peptide of thrombopoietin (TPO).

As used herein, the phrase “carboxy terminal peptide of thrombopoietin (hereinafter referred to as TpS)” refers to amino acids at positions 176 to 353 of thrombopoietin,

particularly the amino acids at positions 337 to 353 of thrombopoietin, or a variant or analog thereof, which has equivalent biological activity.

The TpS of the invention includes, but is not limited to, SEQ ID NO: 4, or a sequence having at least 65%, 70%, 80%, or 90% sequence identity to SEQ ID NO: 4, preferably at least 95%, or 99% sequence identity.

The TpS of the present invention may be attached to the EPO (at the N-ter or C-ter), the highly glycosylated peptide (at the N-ter or C-ter) and/or the CTP (at the N-ter or C-ter), and the amount of the TpS is not limited. In one embodiment, one or more the same or different TpS can be attached to the N-ter of the EPO or C-ter of the highly glycosylated peptide. In another embodiment, one or more the same or different TpS can be attached to the N-ter of EPO or the C-ter of the CTP.

The TpS of the present application may acts as a protectant against degradation of proteins or peptides derived therefrom. The TpS can extend circulatory half-life of the recombinant proteins, and enhance the potency of the recombinant proteins.

In the present invention, the amount and arrangement of EPO, the highly glycosylated peptide, CTP, and TpS are not limited.

In one embodiment, the recombinant protein of the present invention comprises SEQ ID NOS: 1, 2, 3, and 4.

In another embodiment, the recombinant protein of the present invention may be selected from SEQ ID NO: 5 (EPO-NNCT), 6 (NNCT-EPO), 7 (EPO-N1N2), 8 (N1N2-EPO), 9 (EPO-N1), or 10 (EPO-N2).

The highly glycosylated peptide, CTP, and TpS also can be modified by deletion, substitution, insertion and/or chemical modification. The method and process of the amino acid deletion, substitution, insertion and/or chemical modification are well known in the art, and the highly glycosylated peptide, CTP, and TpS still maintain the original activity after modification.

In one embodiments, modifications include, but are not limited to N terminus modification, C terminus modification, polypeptide bond modification, such as $\text{CH}_2\text{-NH}$, $\text{CH}_2\text{-S}$, $\text{CH}_2\text{-S=O}$, O=C-NH , $\text{CH}_2\text{-O}$, $\text{CH}_2\text{-CH}_2$, S=C-NH , CH=CH , or CF=CH , backbone modifications, and residue modification. Methods for preparing peptidomimetic compounds are well known in the art and can be referred to Quantitative Drug Design, C. A. Ramsden Gd., Chapter 17.2, F. Choplin Pergamon Press (1992).

In one embodiment, the peptide bond (-CO-NH-) of the polypeptide can be substituted by, such as, N-methyl bond ($\text{-N(CH}_3\text{)-CO}$), ester bond (-C(R)H-COOC(R)-N-),

ketomethylen (-CO-CH₂), α-aza bond (-NH-N(R)-CO-), where R is any alkyl, hydroxyethylene bond (-CH(OH)-CH₂-), thioamide (-CS-NH-), alkene bonds (-CH=CH-), amide bond (-NH-CO-), or polypeptide derivative (-N(R)-CH₂-CO-).

The present invention further provides a polynucleotide encoding the recombinant protein of the present invention.

The phrase "a polynucleotide or nucleotide" refers to a single or double stranded nucleic acid sequence which be isolated and provided in the form of an RNA sequence, a complementary polynucleotide sequence (cDNA), a genomic polynucleotide sequence and/or a combination of the above.

The polynucleotides of the present invention may be prepared using PCR techniques, or any other method or procedure known to one skilled in the art. The procedure involves the ligation of two different DNA sequences (See, for example, "Current Protocols in Molecular Biology", eds. Ausubel et al., John Wiley & Sons, 1992).

The polynucleotides of the invention may be inserted into expression vectors to enable expression of the recombinant protein. In one embodiment, the expression vector includes additional sequences which render this vector suitable for replication and integration in prokaryotes or eukaryotes. In another embodiment, expression vectors comprise transcription and translation initiation sequences (e.g., promoters or enhances) and transcription and translation terminators (e.g., polyadenylation signals).

A variety of prokaryotic or eukaryotic cells can be used as host-expression systems to express the polypeptides of the present invention. In one embodiment, these expression systems include, but are not limited to, microorganisms, such as bacteria, yeast, plant cell, eukaryotes (e.g. mammalian cells, CHO cells), etc.

Methods for transformation can be found in Sambrook et al., Molecular Cloning: A Laboratory Manual, Cold Springs Harbor Laboratory, New York (1989, 1992), in Ausubel et al., Current Protocols in Molecular Biology, John Wiley and Sons, Baltimore, Md. (1989), Chang et al., Somatic Gene Therapy, CRC Press, Ann Arbor, Mich. (1995), Vega et al., Gene Targeting, CRC Press, Ann Arbor Mich. (1995), Vectors: A Survey of Molecular Cloning Vectors and Their Uses, Butterworths, Boston Mass. (1988) and Gilboa et al. [Biotechniques 4 (6): 504-512, 1986], and include, for example, stable or transient transfection, lipofection, electroporation and infection with recombinant viral vectors.

The present invention of the invention further provides a composition, comprising the recombinant protein of the invention and a physiologically acceptable carrier or excipient.

The phrases "pharmaceutically acceptable carrier or excipient" which be

interchangeably used refer to a carrier, excipient or adjuvant that does not cause significant irritation to an organism and does not abrogate the biological activity and properties of the administered compound. The carrier comprises, but is not limited to polyethylene glycol (PEG), a biocompatible polymer with solubility in both organic and aqueous media. The excipients include, but are not limited to calcium carbonate, calcium phosphate, various sugars and starch, cellulose derivatives, gelatin, vegetable oils and polyethylene glycols.

The composition of the present invention can be used to treat a patient having anemia, an anemic patient having chronic renal insufficiency, an anemic patient having end stage renal disease, an anemic patient undergoing dialysis, an anemic patient having chronic renal failure, an anemic HIV infected patient, an anemic patient having cancer, an anemic patient undergoing chemotherapy, and an anemic patient scheduled to undergo non-cardiac, non-vascular surgery.

After an effective amount of the composition of the present invention is administered to an anemia patient, the hematocrit (Ht) of anemia patient can be increased significantly, and the recombinant EPO with high glycosylation of the present invention has a longer half-life in a subject. The recombinant EPO with high glycosylation of the present invention has a longer half-life than that of the commercial EPO products (e.g., Eprex® and Aranesp®). For example, the high-glycosylated EPO of the present invention has a half-life at least about 1 time longer than the commercial EPO products, preferably, 2 times, more preferably, 3 times. In another embodiment, the high-glycosylated EPO of the present invention has a longer half-life, a higher AUC (area under curve) and Cmax, and a longer Tmax values than that of the commercial EPO products (e.g., Eprex® and Aranesp®).

The phrase “therapeutically effective” generally refers to from about 1 to 10000 I.U./kg, preferably from about 50 to 2000 I.U./kg, more preferably from about 50 to 600 I.U./kg, and most preferably from about 50 to 300 I.U./kg body weight. The formulations of the present invention may be administered at any desired frequency or time interval between administrations. A dosing regimen, the subject is administered the sustained release formulations of the present invention thrice per two weeks, once per week, once per two weeks, once per three weeks, once per month, once per five weeks, once per six weeks, or at more frequent or less frequent intervals, or at any combination of frequencies or time intervals as desired. The dosage required will vary according to a number of factors known to those skilled in the art, including, but not limited to, the compound or compounds used, the species of subject, the size of the subject, and the severity of the associated disease condition

that anemia. A preferred dosing regimen may be once per three weeks, particularly for subjects receiving chemotherapy for the treatment of cancer, since many chemotherapeutic regimens are administered on a once per three-week schedule.

EXAMPLE

EXAMPLE 1

Host cells

Cells were purchased from the Culture Collection and Research Center (CCRC, 60133) of Food Industry Research and Development Institute, Taiwan. CHO dhfr- cells were cultured in IMDM medium (Isocoves Modified Dulbecco's Medium, IMDM, Gibco Cat. 12200-36) supplemented with 10% fetal bovine serum (Gibco Cat. 10091148) plus hypoxanthine and thymidine (Gibco, Cat. 11067-030) and 2 mM L-glutamine (Gibco Cat. 25030-081). Dhfr(-) marker was used for amplification and selection. Expression of the dhfr gene could be amplified by challenging with the dihydrofolate reductase inhibitor, methorexate (MTX, Sigma Cat no. M8407). When the dhfr genes were amplified, other neighboring genes often were co-amplified, so that after each round of amplification cells were subcloned to select clones with increased production rates. Cells were cultured in a 37 °C humidified 95% air /5% CO₂ incubator (Model 3326, Forma scientific).

EXAMPLE 2

Construction of the expression vectors

2.1 EPO-NNCT

EPO-NNCT gene fragment was obtained using assembly PCR method and then inserted into pcDNA3.1/Neo (+)/DHFR vector, yielding pND/EPO-NNCT. The expression vector construct contained the neomycin-resistance gene as a selective marker. EPO-NNCT gene was shown in **Fig. 1**, wherein the "EPO" is an erythropoietin, "N1" is highly glycosylated peptide 1 (SEQ ID NO: 1), "N2" is highly glycosylated peptide 2 (SEQ ID NO: 2), "CTP" is the carboxy terminal peptide of hCG (SEQ ID NO: 3), and "TpS" is the carboxy terminal peptide of thrombopoietin (SEQ ID NO: 4).

2.2 NNCT-EPO

The DNA fragment of NNCT was reproduced by PCR using LSP-N-S1 primer (3'-cctagggccaccatgggggtgcacgaatgtcctgcctggctgtggcttctcctgtccctgctgctcctctgg-5'), LSP-N-S2 primer (3'-ctgtccctgctgctgctcctctgggctcccagtcctgggcgaggccgagaatatcacgacgggcggtaac-5'), and ENNCT1-A primers (3'-ctcggctgtcacagatgagggcgtgggtggggcccttctgagacagattctgggagtgggtgtaggatg-5') from pND/EPO-NNCT plasmid to obtain NNCT-EPO fragment as shown in **Fig. 1**. The NNCT-EPO fragment then was inserted into an expression vector to obtain pPD/NNCT-EPO vector. The expression vector contained the puromycin-resistance gene as a selective marker.

2.3 EPO-N1N2

The DNA fragment of EPO-N1N2 was reproduced by PCR using E-S primer (3'-cctagggccaccatgggggtgcacgaatgtcctgcc-5') and ENNCT2-A primer (3'-gtatacctacagctgcagagtctcgttcacctgggaagag-5') from pND/EPO-NNCT plasmid to obtain EPO-N1N2 fragment as shown in **Fig. 1**. The EPO-N1N2 fragment then was inserted into an expression vector to obtain pPD/EPO-N1N2 vector. The expression vector contained the puromycin-resistance gene as a selective marker.

2.4 N1N2-EPO

The DNA fragment of N1N2-EPO was synthesized by GENEWIZ, Inc (as shown in **Fig. 1**), and it was inserted into an expression vector to obtain pPD/N1N2-EPO vector. The expression vector contained the puromycin-resistance gene as a selective marker.

2.5 EPO-N1

The DNA fragment of EPO-N1 was reproduced by PCR using E-S primer (3'-cctagggccaccatgggggtgcacgaatgtcctgcc-5') and ENNCT4-A primer (3'-gtatacctagtctgggacagtgatattctc-5') from pND/EPO-NNCT plasmid as shown in **Fig. 1**. The EPO-N1 fragment was inserted into an expression vector to obtain pPD/EPO-N1. The expression vector contained the puromycin-resistance gene as a selective marker.

2.6 EPO-N2

The DNA fragment of EPO-N2 was obtained by PCR method using E-S primer (3'-cctagggccaccatgggggtgcacgaatgtcctgcc-5') and ENNCT5-A primer (3'-gtatacctacagctgcagagtctcgttcacctgggaagagttgaccaacagtctgtcccctgtcctgcaggcctccc-5') from pND/EPO-NNCT plasmid to obtain EPO-N2 fragment as shown in **Fig. 1**. EPO-N2 fragment then was inserted into an expression vector to obtain pPD/N1 plasmid. The expression vector contained the puromycin-resistance gene as a selective marker.

EXAMPLE 3

Establishment of the recombinant cell lines

Vector containing EPO-NNCT gene was transfected into CHO dhfr- cells by electroporation (PA4000 PulseAgile® electroporator, Cyto Pulse Sciences). Cells were first trypsinized and resuspended at a concentration of 3×10^6 cells/ml in CP-T buffer (Cyto pluse Cat. CP-T). 200 μ l of cell suspension (6×10^5 cells) was mixed with 10 μ g pND/BMP2 and electrophoresed. Electrophoresed cells were cultured in a complete medium (IMDM with 10% fetal bovine serum and HT supplement) without selective substance for recovery growth. After 48 hours growth in medium without selective substance, the cells were transferred to the complete medium containing IMDM, 10% fetal bovine serum, L-glutamine and 5 nM MTX, with selective substance. After approximately 2-week culture period, cell lines were transferred to 96-well plates, and cell lines which express high level of rhBMP-2 were selected through quantifying protein level by ELISA. The selected cells were cultured in a selective medium. The cells were diluted to the concentration of 1 cell/100 μ l and then transferred to a 96-well plate to culture to grow to cell clusters. Cells with high expression level were screened according to the results of ELISA and MTX concentrations were gradually increased from 0.005, 0.01, 0.02 to 0.05 μ M.

EXAMPLE 4

Batch culture

4×10^5 cell/ml of recombinant cell line obtained from Example 3 were batch-cultured in 50 ml flask containing serum free medium. Cells were monitored everyday and culture medium was collected to measure the concentration of the EPO and select a high-yield clone under 0.02 μ M MTX challenge. In spinner culture, the accumulated productivity of EPO-NNCT was 140.69 μ g/ml as shown in Table 1.

Table 1 Results of batch culture

Max. Yield (μ g/ml)	140.9
Max. cell concentration (10^6 cell/ml)	2.42
IVC (10^6 cell-day)	14.60
q (pg/cell/day)	9.63

EXAMPLE 5

Bioactivity assay

The process and procedure of the example were carried out according to the disclosure of European Pharmacopeia 5.2 (Erythropoietini solution concentrata). Female 8-week-old BALB/c mice were classified into two groups, and injected subcutaneously with 21, 42, 84, 168, 336, and 672 ng/ml of EPO-NNCT of the invention and Eprex®, individually. After injection, the 0.25 ml whole blood was collected. After the cells were stained, the cells were analyzed by flow cytometry and CellQuest Pro software, and the results were shown in Table 2. Referring to **Fig. 2**, in the same dosage, the average number of reticulocytes of the mice administered with EPO-NNCT of the present invention was higher than that of the mice administered with Eprex®.

Table 2 Amount of Reticulocytes after injection

	Subcutaneous injection (ng/ml)	Reticulocytes (mean %)
EPO-NNCT	672	23.15
	336	19.45
	168	16.14
	84	13.17
	42	11.47
	21	10.52
Eprex®	672	15.50
	336	14.05
	168	11.57

25 female 8-week-old BALB/c mice were classified into five groups, and injected subcutaneously with 336 ng/ml of EPO-NNCT and Eprex®, individually. The mice whole blood was collected at 4 to 9, and 13 days after injection. The percentage of reticulocyte was determined by flow cytometry and analyzed by CellQuest Pro software. As shown in Table 3, the amount (mean %) of reticulocytes was highest at Day 7 in the mice injected with the EPO-NNCT of the invention and significantly higher than that of Eprex®.

Table 3 Amount of Reticulocytes at different Day after injection

	Day	Reticulocytes (Mean %)	S.D.	CV
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EPO-NNCT	5	20.33	2.38	11.70
	6	27.26	1.99	7.29
	7	28.12	2.11	7.51
	8	25.42	2.17	8.55
	9	16.37	3.09	18.89
	13	5.21	0.53	10.19
Eprex®	5	11.28	1.56	13.86
	6	7.42	0.81	10.97
	7	6.35	1.16	18.22
	8	11.11	1.22	10.95
	9	10.76	2.40	22.31
	13	8.61	0.92	10.67

EXAMPLE 6

Pharmacokinetic assay

14 female 8-week-old BALB/c mice were classified into four groups, and intravenously and subcutaneously injected with 2000 IU/kg of EPO-NNCT of the invention, Eprex®, and Aranesp®, individually. The mice blood was collected at 5 min, 10 min, 30 min, 1 hr, 2 hr, 5 hr, 8 hr, 24 hr, 30 hr, 48 hr, 72 hr, 96 hr, 120 hr, 168 hr, 216 hr, 264 hr, and 336 hr after injection, centrifuged to obtain the serum, and then the serum was stored at -70°C. The pharmacokinetic assay was carried out using Quantikine® IVD® Epo ELISA kit to measure the optical density at 450 nm and 600 nm and then analyzed by SoftMax® Pro 5 software. The results are shown in Table 4. Referring to **Figs 3-4**, compared to Eprex® and Aranesp®, EPO-NNCT of the present invention had a longer half-life (about 25-26 hours), and a higher AUC (area under the curve) value (about 8387-4502 ng·hr/ml).

Table 4 Pharmacokinetic properties of EPO-NNCT

	half-life (hr)	AUC (ng·hr/ml)	Cmax (ng/ml)	Tmax (hr)
intravenous injection				
EPO-NNCT (n=2)	25.03	8387.44	-	-
Aranesp® (n=2)	17.89	5694.75	-	-
Eprex® (n=3)	6.35	269.96	-	-
subcutaneous injection				
EPO-NNCT (n=2)	26.53	4502.90	68.19	24
Aranesp® (n=2)	17.78	2547.34	58.16	24
Eprex® (n=3)	7.14	169.55	6.88	10

Similarly, compared to Eprex®, EPO-N1N2, N1N2-EPO, and NNCT-EPO of the present invention also had a longer half-life (21-30 hours), and a higher AUC (Area Under Curve) value (370-981 ng·hr/ml), as shown in Table 5.

Further, EPO-N1 and EPO-N2 had a Tmax of about 24 hours. Accordingly, it is known that EPO-N1 and EPO-N2 had a higher Tmax as compared to commercial Eprex®.

Table 5 Pharmacokinetic properties of EPO-N1N2, N1N2-EPO, NNCT-EPO and Eprex® (subcutaneous injection)

	half-life (hr)	AUC (ng·hr/ml)	Cmax (ng/ml)	Tmax (hr)
EPO-N1N2	21.76	370.47	11.77	24
N1N2-EPO	30.14	448.04	13.78	30
NNCT-EPO	25.50	981.63	26.18	24
Eprex®	7.14	169.55	6.88	10

Although preferred embodiments are disclosed as above, they cannot be used to limit the present invention, and anyone skilled in the art can make some changes and modifications without exceeding the spirit and scope of the present invention, and thus the scope of the present invention will be limited only by the appended claims.

SYMBOL DESCRIPTION

EPO: Erythropoietin

N1: Highly glycosylated fragment 1

N2: Highly glycosylated fragment 2

CTP: Harboxy terminal peptide of human chorionic gonadotropin

TpS: Carboxy terminal peptide of thrombopoietin

CLAIMS:

1. A recombinant protein, comprising an erythropoietin and a highly glycosylated peptide located on the N-ter or C-ter of the erythropoietin, wherein the highly glycosylated peptide comprises a sequence identical to SEQ ID NO: 1 and 2.

2. The recombinant protein according to claim 1, wherein the carboxy-terminal end of the erythropoietin is attached to the highly glycosylated peptide.

3. The recombinant protein according to claim 1, wherein the amino-terminal end of the erythropoietin is attached to the highly glycosylated peptide.

4. The recombinant protein according to claim 1, further comprising a carboxy terminal peptide of human chorionic gonadotropin.

5. The recombinant protein according to claim 4, wherein the carboxy terminal peptide of human chorionic gonadotropin comprises a sequence identical to SEQ ID NO: 3.

6. The recombinant protein according to claim 5, wherein the carboxy-terminal end of the highly glycosylated peptide is attached to the carboxy terminal peptide of human chorionic gonadotropin.

7. The recombinant protein according to claim 4, further comprising a carboxy terminal peptide of thrombopoietin.

8. The recombinant protein according to claim 7, wherein the carboxy terminal peptide of thrombopoietin comprises a sequence identical to SEQ ID NO: 4.

9. The recombinant protein according to claim 7, wherein the carboxy-terminal end of the carboxy terminal peptide of human chorionic gonadotropin is attached to the carboxy terminal peptide of thrombopoietin.

10. The recombinant protein according to claim 9, wherein the recombinant protein comprises SEQ ID NO: 5.

11. A nucleotide sequence encoding the recombinant protein of claim 1.

12. A cell transfected with the nucleotide sequence as claimed in claim 11 for expressing the recombinant protein of claim 1.

13. A composition comprising the recombinant protein of claim 1 and a pharmaceutically acceptable carrier or adjuvant.

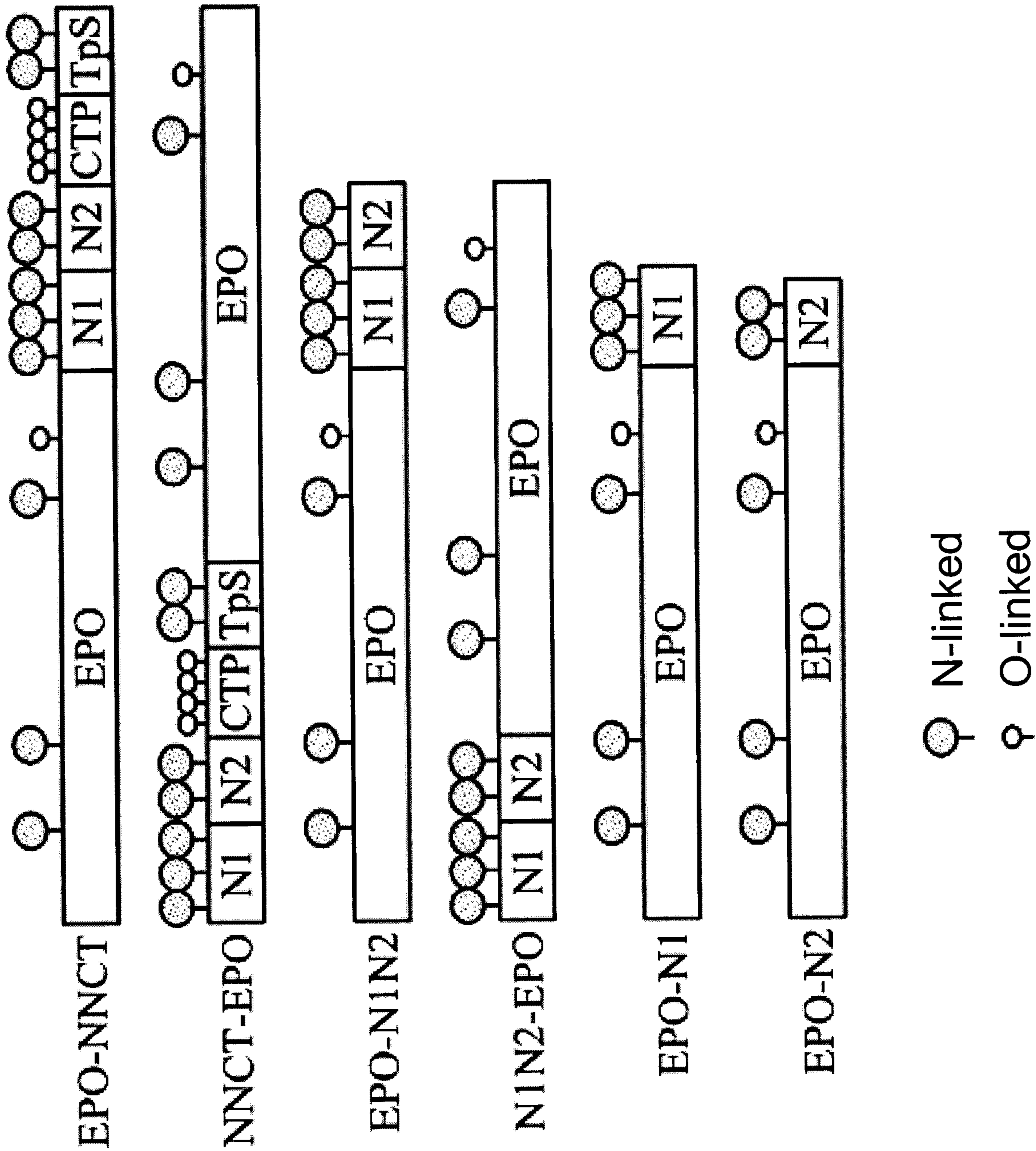


Fig. 1

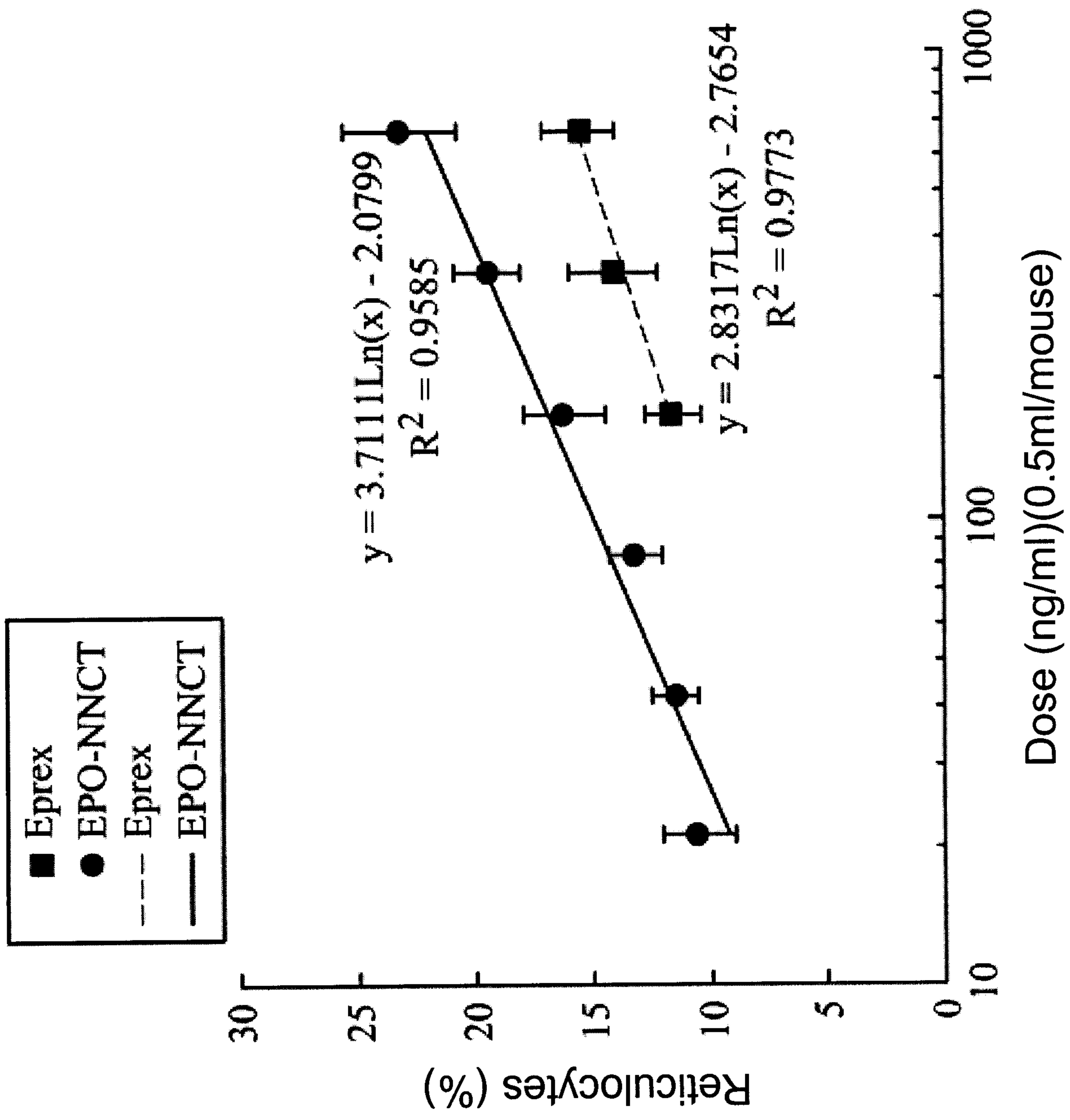


Fig. 2

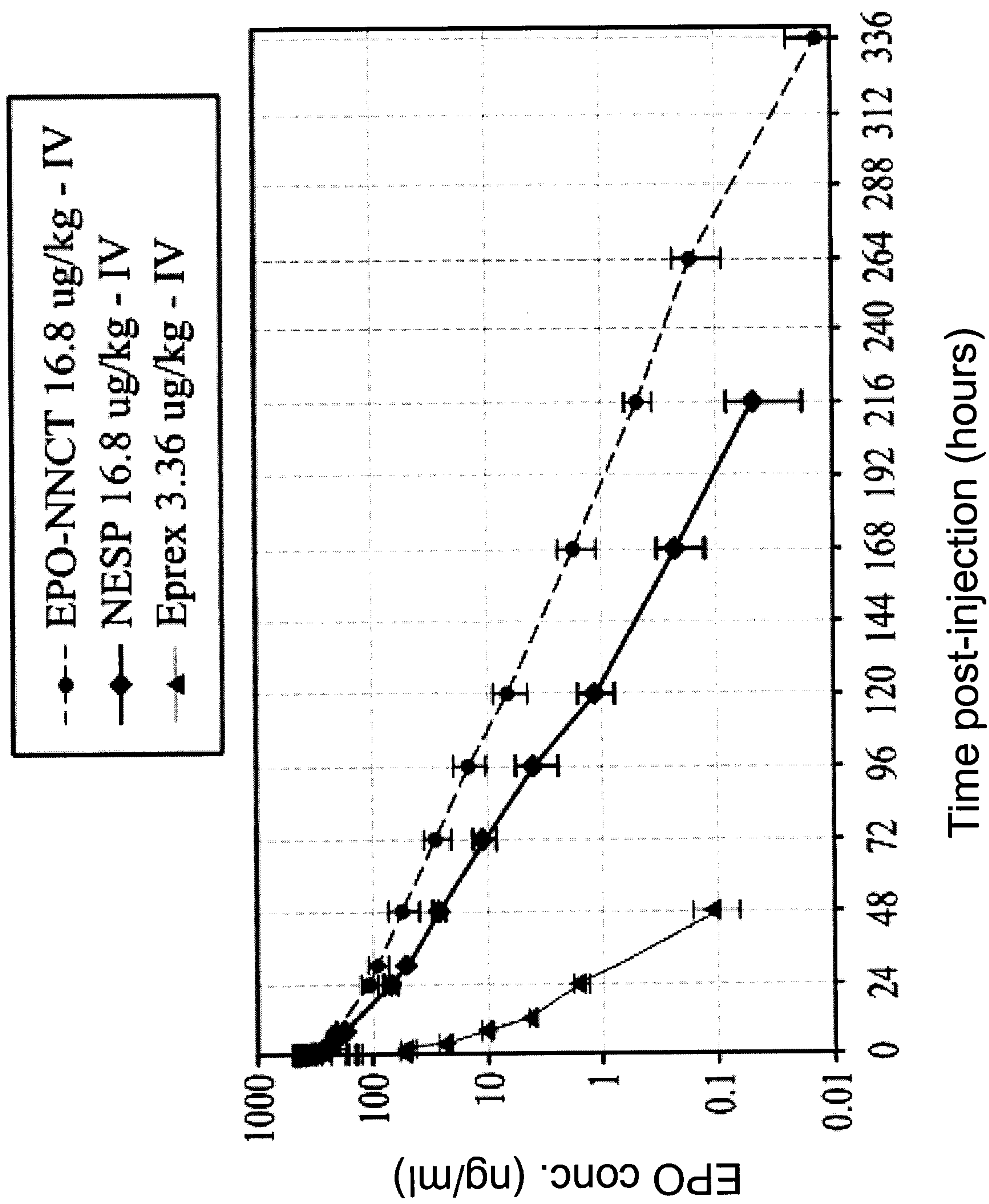


Fig. 3

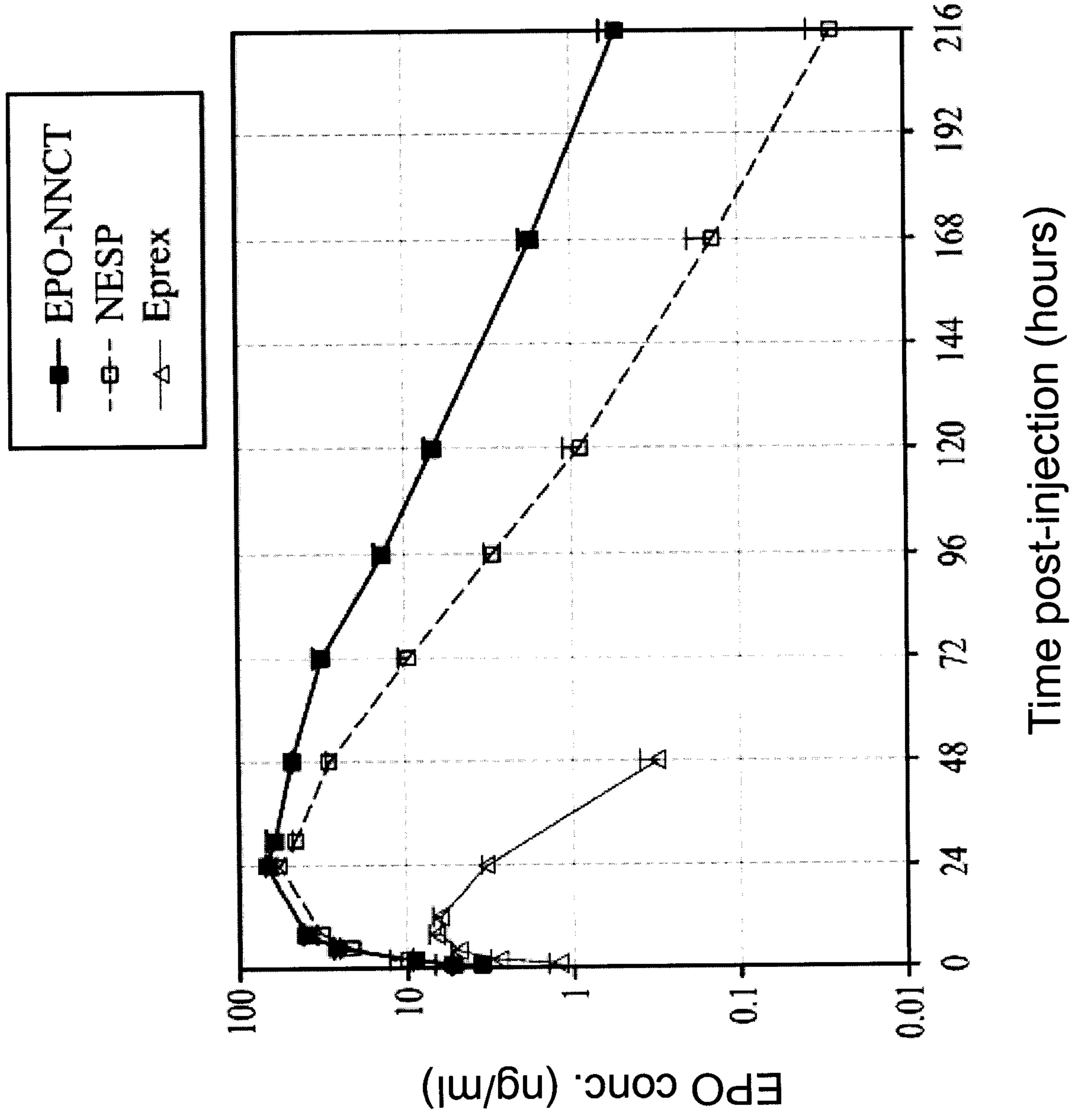


Fig. 4

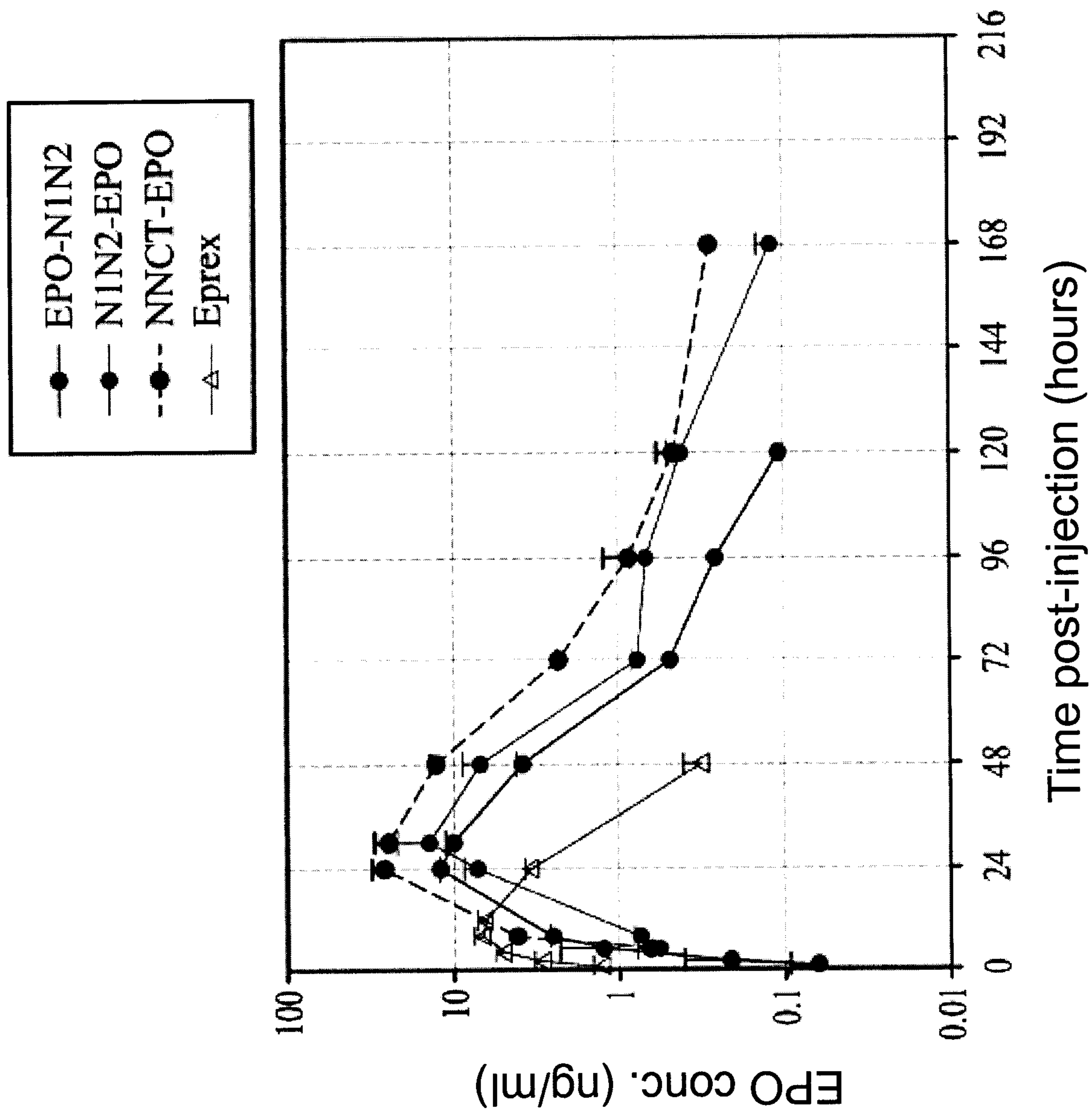


Fig. 5