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(54) **Title:** PROCESS FOR THE EFFICIENT PRODUCTION OF 7-ADCA VIA 3-(CARBOXYETHYLTHIO)PROPIONYL-7-ADCA

(57) **Abstract**

An overall efficient process for the preparation and recovery of 7-aminodesacetoxycephalosporanic acid (7-ADCA) via 3-(carboxyethylthio)propionyl-7-ADCA, using a *Penicillium chrysogenum* transformant strain expressing expandase in conjunction with acyltransferase, is provided.

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PROCESS FOR THE EFFICIENT PRODUCTION OF 7-ADCA VIA 3-(CARBOXYETHYLTHIO)PROPIONYL-7-ADCA

Field of the invention and brief description of the prior art

The present invention concerns a biosynthetic process for preparation and recovery of 7-aminodesacetoxycephalosporanic acid (7-ADCA).

ß-Lactam antibiotics constitute the most important group of antibiotic compounds, with a long history of clinical use. Among this group, the prominent ones are the penicillins and cephalosporins. These compounds are naturally produced by the filamentous fungi Penicillium chrysogenum and Acremonium chrysogenum, respectively.

As a result of classical strain improvement techniques, the production levels of the antibiotics in Penicillium chrysogenum and Acremonium chrysogenum have increased dramatically over the past decades. With the increasing knowledge of the biosynthetic pathways leading to penicillins and cephalosporins, and the advent of recombinant DNA technology, new tools for the improvement of production strains and for the in vivo derivatization of the compounds have become available.

Most enzymes involved in ß-lactam biosynthesis have been identified and their corresponding genes been cloned, as can be found in Ingolia and Queener, Med. Res. Rev. 9 (1989), 245-264 (biosynthesis route and enzymes), and Aharonowitz, Cohen, and Martin, Ann. Rev. Microbiol. 46 (1992), 461-495 (gene cloning).

The first two steps in the biosynthesis of penicillin in P. chrysogenum are the condensation of the three amino acids L-5-amino-5-carboxypentanoic acid (L-α-aminoadipic acid) (A), L-cysteine (C) and L-valine (V) into the tripeptide LLD-ACV, followed by cyclization of this tripeptide to form isopenicillin N. This compound contains the typical ß-lactam structure.

The third step involves the exchange of the hydrophilic side chain of L-5-amino-5-carboxypentanoic acid by a hydrophobic side chain by the action of the enzyme acyltransferase (AT). In the

industrial process for penicillin G production the side chain of choice is phenylacetic acid (PA). In EP-A-0532341 the application of an adipate (5-carboxypentanoate) feedstock has been disclosed. The incorporation of this substrate leads to a penicillin derivative with a 5-carboxypentanoyl side chain, viz. 5-carboxypentanoyl-6-aminopenicillanic acid. This incorporation is due to the fact that the acyltransferase has a proven wide substrate specificity (Behrens et al., J. Biol. Chem. 175 (1948), 751-809; Cole, Process. Biochem. 1 (1966), 334-338; Ballio et al., Nature 185 (1960), 97-99). The enzymatic exchange reaction mediated by AT takes place inside a cellular organelle, the microbody, as has been described in EP-A-0448180.

Cephalosporins are much more expensive than penicillins. One reason is that some cephalosporins (e.g. cephalexin) are made from penicillins by a number of chemical conversions. Another reason is that, so far, only cephalosporins with a D-5-amino-5-carboxypentanoyl side chain can be fermented. Cephalosporin C, by far the most important starting material in this respect, is very soluble in water at any pH, thus implying lengthy and costly isolation processes using cumbersome and expensive column technology. Cephalosporin C obtained in this way has to be converted into therapeutically used cephalosporins by a number of chemical and enzymatic conversions.

The intermediate 7-ADCA is currently produced by chemical derivatization of penicillin G. The necessary chemical steps to produce 7-ADCA involve the expansion of the 5-membered penicillin ring structure to a 6-membered cephalosporin ring structure. However, the expandase enzyme from the filamentous bacterium Streptomyces clavuligerus can carry out such ring expansions. When introduced into P. chrysogenum, it can convert the penicillin ring structure into the cephalosporin ring structure, as described in Cantwell et al., Proc. R. Soc. Lond. B. 248 (1992), 283-289; and in EP-A-0532341 and EP-A-0540210. The expandase enzyme has been well characterized (EP-A-0366354) both biochemically and functionally, as has its corresponding gene. Both physical maps of the cefE gene (EP-A-0233715), DNA sequence and transformation studies in P. chrysogenum with cefE have been described.

Another source for a suitable ring expansion enzyme is the filamentous bacterium Nocardia lactamdurans (formerly Streptomyces lactamdurans). Both the biochemical properties of the enzyme and the DNA sequence of the gene have been described (Cortés et al., J. Gen. Microbiol. 133 (1987), 3165-3174; and Coque et al., Mol. Gen. Genet. 236 (1993), 453-458, respectively).

More particularly, EP-A-0532341 teaches the in vivo use of the expandase enzyme in P. chrysogenum, in combination with a 5-carboxypentanoyl side chain as a feedstock, which is used as a substrate for the acyltransferase enzyme in P. chrysogenum. This leads to the formation of 5-carboxypentanoyl-6-APA, which is converted by an expandase enzyme introduced into the P. chrysogenum strain to yield 5-carboxypentanoyl-7-ADCA. Finally, the removal of the 5-carboxypentanoyl side chain is suggested, yielding 7-ADCA as a final product. The patent application EP-A-0540210 describes a similar process for the preparation of 7-ACA, including the extra steps of converting the 3-methyl side chain of the ADCA ring into the 3-acetoxymethyl side chain of ACA. However, the aforesaid patent applications do not teach an efficient and economically effective process, because, first of all, the problem of timely expression of the expandase enzyme in the cell concomitant with the expression of the acyltransferase enzyme has not been recognized.

In contrast, the present invention provides an efficient process for producing 7-ADCA in which expandase and acyltransferase are expressed simultaneously.

In addition, the application of a new side chain precursor, viz. 3,3'-thiodipropionic acid, is taught by the present invention. This precursor is very efficiently incorporated by P. chrysogenum into the corresponding penicillins, which are to be expanded by the subsequent action of the expandase enzyme.

Furthermore, until now no effective way has been described for recovering the 7-ADCA derivative from the fermentation broth before its deacylation. The present invention provides an effective solvent extraction procedure for the recovery of the 7-ADCA derivative.

By the present invention, a real efficient overall process is provided for the preparation of 7-ADCA, comprising reaction steps neither disclosed nor suggested in the prior art so far.

Also, by applying the present invention and analogous to the description given in EP-A-0540210, 7-ACA can be prepared in an efficient overall process in this way.

Brief description of the figures

Figure 1: A functional map of plasmid pMcTNE.

Figure 2: A functional map of plasmid pMcTSE.

Figure 3: A functional map of plasmid pMcTNde.

Figure 4: A functional map of plasmid pGNETA.

Figure 5: A functional map of plasmid pGSETA.

Figure 6: A functional map of plasmid pANETA.

Figure 7: A functional map of plasmid pASETA.

Figure 8: DNA sequence of Nocardia lactamdurans cefE (Coque et al., supra) (lower lines) alligned with sequence PCR product 1 (upper lines).

Brief description of the sequence listing

Sequence ID Nos. 1 to 13: oligonucleotides used in the construction of a P. chrysogenum expression cassette for the Streptomyces clavuligerus and Nocardia lactamdurans cefE genes.

Sequence ID No. 14: DNA sequence of Nocardia lactamdurans cefE (Coque et al., supra).

Summary of the invention

The present invention thus provides a process for the preparation and recovery of 7-aminodesacetoxycephalosporanic acid (7-ADCA) by:

a) transforming a Penicillium chrysogenum strain with an expandase gene, under the transcriptional and translational regulation of filamentous fungal expression signals;

b) fermenting said strain in a culture medium and adding to said culture medium 3,3'-thiodipropionic acid or a salt or ester thereof suitable to yield 3-(carboxyethylthio)propionyl-6-aminopenicillanic acid (3-(carboxyethylthio)propionyl-6-APA), which are in situ expanded to form 3-(carboxyethylthio)propionyl-7-ADCA;

c) recovering the 3-(carboxyethylthio)propionyl-7-ADCA from the fermentation broth;

d) deacylating said 3-(carboxyethylthio)propionyl-7-ADCA; and

e) recovering the crystalline 7-ADCA.

Preferably, step (e) is a filtration step.

Preferably, the expression of the expandase gene is under the transcriptional and translational regulation of the respective control elements of the AT-gene, providing a simultaneous timing of expression of said genes.

Preferably, 3-(carboxyethylthio)propionyl-7-ADCA are recovered from the fermentation broth by extracting the broth filtrate with an organic solvent immiscible with water at a pH of lower than about 4.5 and back-extracting the same with water at a pH between 4 and 10.

Moreover, a recombinant DNA vector comprising the DNA encoding expandase, functionally linked to the transcriptional and translational control elements of the AT-gene of P. chrysogenum or the A. nidulans gpdA gene, and host cells transformed with the same, are provided.

Detailed description of the invention

The present invention concerns the use of functional gene constructs in P. chrysogenum for the in vivo expansion of the penicillin ring structure, in combination with the use of a new substrate for the biosynthetic enzymes to form a derivative of a key intermediate in the cephalosporin biosynthesis, 7-amino-desacetoxycephalosporanic acid, or 7-ADCA. This derivative has a chemical composition so as to allow efficient solvent extraction, thus providing an economically attractive recovery process.

Transformation of P. chrysogenum can, in principle, be achieved by different means of DNA delivery, like PEG-Ca mediated protoplast uptake, electroporation or particle gun techniques, and selection of transformants. See for example Van den Hondel en Punt, Gene Transfer and Vector Development for Filamentous Fungi, in: Applied Molecular Genetics of Fungi (Peberdy, Laten, Ogden, Bennett, eds.), Cambridge University Press (1991). The application of dominant and non-dominant selection markers has been described (Van den Hondel, supra). Selection markers of both homologous (P. chrysogenum derived) and heterologous (non-P. chrysogenum derived) origin have been described.

The application of the different transformant selection markers, homologous or heterologous, in the presence or absence of vector sequences, physically linked or not to the non-selectable DNA, in the selection of transformants are well known.

Preferably a homologous selection marker is used to select transformants of P. chrysogenum to limit the amount of heterologous DNA introduced into P. chrysogenum. Most preferably a dominant selection marker is used which can be selectively removed from the transformed strain, e.g. the amdS gene of A. nidulans or other filamentous fungi (European patent application No. 94201896.1). These preferred characteristics of the P. chrysogenum transformant selection marker are very beneficial in process and product registration procedures since no antibiotic resistance markers are involved in the process or will be introduced into the environment.

The most preferred embodiment, the amdS selection marker which can be selectively removed from the strain, allows repeated rounds of transformation using the same dominant selection over and over again. This selection-marker free feature of the novel expandase expressing P. chrysogenum strains is crucial for the rapid development of high-producing strains in an industrial strain improvement programme.

The ring-expansion reaction, mediated by the expandase enzyme is introduced into and expressed in this way in P. chrysogenum, for instance in strain Wisconsin 54-1255. This ring-expansion reaction is also carried out in mutants thereof having an improved

β-lactam yield. It will be clear that in that case, the medium conditions have to be slightly adapted to obtain an efficient growth.

Furthermore, the cefE gene is placed under the transcriptional and translational control of the respective filamentous fungal gene control elements, preferably derived from P. chrysogenum acyltransferase (AT) gene, thus allowing its expression in the optimal time frame, synchronized with the action of the acyltransferase enzyme itself. These measures are crucial for the effectiveness of the ring-expansion reaction on the penicillin molecule.

In addition to synchronised expression of the expandase and acyltransferase encoding genes, intracellular co-localisation of part of the expandase enzymes with acyltransferase in microbodies (the intracellular location of acyltransferase) might be advantageous for the development of an economical production process. These preferred embodiments will contribute enormously to reduce the amount of penicillin by-products, which are not tolerated in the 7-ADCA end product by registration authorities.

In summary, the present invention teaches how the activity of an expandase enzyme introduced into P. chrysogenum can be dedicated to the ring expansion of the penicillin ring in terms of synchronized expression.

In accordance with this invention ß-lactam intermediates 3-(carboxyethylthio)propionyl-7-ADCA, are produced in P. chrysogenum by adding 3,3'-thiodipropionic acid or a salt or ester thereof. Suitable salts are for instance those of sodium or potassium. The same are efficiently recovered from the media through a simple solvent extraction, for instance, as follows:

The broth is filtered and an organic solvent immiscible with water is added to the filtrate. The pH is adjusted in order to extract the cephalosporin from the aqueous layer. The pH range has to be lower than 4.5; preferably between 4 and 1, more preferably between 2 and 1. In this way the cephalosporin is separated from many other impurities present in the fermentation broth. Preferably a small volume of organic solvent is used, giving a concentrated solution of the cephalosporin, so achieving reduction of the volumetric flow rates. A second possibility is

whole broth extraction at a pH of 4 or lower. Preferably the broth is extracted between 4 and 1 with an organic solvent immiscible with water.

Any solvent that does not interfere with the cephalosporin molecule can be used. Suitable solvents are, for instance, butyl acetate, ethyl acetate, methyl isobutyl ketone, alcohols like butanol etc.. Preferably 1-butanol or isobutanol are used.

Hereafter the cephalosporin is back extracted with water at a pH between 4 and 10, preferably between 6 and 9. Again the final volume is reduced drastically. The recovery can be carried out at temperatures between 0 and 50°C, and preferably at ambient temperatures.

The aqueous cephalosporin solution thus obtained is treated with a suitable enzyme in order to remove the 3-(carboxyethylthio)propionyl side chain and obtain the desired 7-ADCA.

Preferably, an immobilized enzyme is used, in order to be able to use the enzyme repeatedly. The methodology for the preparation of such particles and the immobilization of the enzymes have been described extensively in EP-A-0222462. The pH of the aqueous solution has a value of, for example pH 4 to pH 9, at which the degradation reaction of cephalosporin is minimized and the desired conversion with the enzyme is optimized. Thus, the enzyme is added to the aqueous cephalosporin solution while maintaining the pH at the appropriate level by, for instance, adding an inorganic base, such as a potassium hydroxide solution, or applying a cation exchange resin. When the reaction is completed the immobilized enzyme is removed by filtration. Another possibility is the application of the immobilized enzyme in a fixed or fluidized bed column, or using the enzyme in solution and removing the products by membrane filtration. Subsequently, the reaction mixture is acidified in the presence of an organic solvent immiscible with water.

Suitable enzymes are, for instance, derived from a Pseudomonas SY77 microorganism having a mutation in one or more of the positions 62, 177, 178 and 179. Also enzymes from other Pseudomonas microorganisms, preferably Pseudomonas SE83, optionally having

a mutation in one or more of the positions corresponding to the 62, 177, 178 and 179 positions in Pseudomonas SY77, may be used.

After adjusting the pH to about 0.1 to 1.5, the layers are separated and the pH of the aqueous layer is adjusted to 2 to 5. The crystalline 7-ADCA is then filtered off.

The deacylation can also be carried out chemically as known in the prior art, for instance, via the formation of an imino-chloride side chain, by adding phosphorus pentachloride at a temperature of lower than 10°C and subsequently isobutanol at ambient temperatures or lower.

The following examples are offered by way of illustration and not by way of limitation.

Examples

Example 1

Expression of the Streptomyces and Nocardia cefE gene in Penicillium chrysogenum

a. General gene cloning and gene transformation procedures

Common techniques used in gene cloning procedures are used in the present application. These techniques include polymerase chain reactions (PCR), synthetic oligonucleotide synthesis, nucleotide sequence analysis of DNA, enzymatic ligation and restriction of DNA, E. coli vector subcloning, transformation, and transformant selection, isolation and purification of DNA, DNA characterization by Southern blot analyses and ^{32}P labelled probes, ^{32}P labelling of DNA by random priming. These techniques are all very well known in the art and adequately described in many references. See for example Sambrook et al., Molecular Cloning, a Laboratory Manual, Cold Spring Harbor, U.S.A. (1989), Innes et al., PCR protocols, a Guide to Methods and Applications, Academic Press (1990), and McPherson et al., PCR, a Practical Approach, IRL Press (1991).

General procedures used in transformation of filamentous fungi and transformant selection include preparation of fungal protoplasts, DNA transfer and protoplast regeneration conditions, transformant purification and characterization. These procedures are all known in the art and very well documented in: Finkelstein and Ball (eds.), Biotechnology of Filamentous Fungi, technology and products, Butterworth-Heinemann (1992); Bennett and Lasure (eds.), More Gene Manipulations in Fungi, Academic Press (1991); Turner, in: Pühler (ed.), Biotechnology, second completely revised edition, VCH (1992).

More specific applications of gene cloning and gene transformation technology to Penicillium chrysogenum are very well documented in Bennett and Lasure (supra) and Finkelstein and Ball (supra).

- Synthetic DNA oligonucleotides are synthesized using a commercial DNA synthesizer (Applied Biosystems, CA, U.S.A.) according to the instructions of the manufacturer.
- PCR is performed using a commercial automatic PCR apparatus (Perkin Elmer, U.S.A.) and Ultma DNA polymerase (Perkin Elmer) according to the instructions of the manufacturer.
- The hGC PCR protocol (Dutton et al., Nucleic Acids Res. 21, (No. 12)(1993) 2953-2954) was used to be able to amplify the cefE coding regions of the N. lactamdurans and the S. clavuligerus chromosomal DNA.
- Restriction enzymes and other DNA modification enzymes are from BRL (MD, U.S.A.) and used according to the instructions of the manufacturer.
- E. coli vector pBluescript® is obtained from Stratagene (CA, U.S.A.).
- Other chemicals used are all analytical grade, obtained from various suppliers.
- DNA nucleotide sequence analysis is performed using an automatic DNA sequence analysis apparatus (Applied Biosystems) based upon detection of sequence-specific fluorescent labelling according to the instructions of the manufacturer.

b. Culturing of microorganisms

Streptomyces clavuligerus ATCC 27064 is grown in tryptic soy broth (Difco). Chromosomal DNA of this strain is used for isolation of the cefE gene (Kovacevic et al., J. Bacteriol. (1989), 754-760).

Nocardia lactamdurans ATCC 27382 is also grown in tryptic soy broth (Difco). Chromosomal DNA of this strain is used for isolation of the cefE gene (Coque et al., supra).

Penicillium chrysogenum Wisconsin 54-1255 (ATCC 28089) is grown in complete YPD medium (YPD; 1% yeast extract, 2% peptone, 2% glucose). Chromosomal DNA of this strain is used for the isolation of penDE gene 5′ and 3′ regulatory regions required for cefE gene expression. Penicillium chrysogenum ATCC 28089 is also used as a host for cefE gene transformation experiments.

Other strains of Penicillium chrysogenum, including mutants of strain Wisconsin 54-1255, having an improved β-lactam yield, are also suitable. Depending on the transformant selection marker used, P. chrysogenum strains containing mutations in the pyrG, niaD or facA gene may be used. These mutant strains can be obtained by methods well-known in the art (Cantoral, Bio/Technol. 5 (1987), 494-497; Gouka et al., J. Biotechn. 20 (1991), 189-200; and Gouka et al., Appl. Microbiol. Biotechnol. (1993), 514-519).

Culturing of P. chrysogenum for generation of protoplasts used in transformation is also done in YPD-medium.

It is well known in the art that the protoplasting and regeneration procedures may differ slightly depending on the particular strain of Penicillium chrysogenum used and the transformant selection procedure applied.

E. coli WK6 (Zell and Fritz, EMBO J. 6 (1987), 1809-1815), XLI-Blue (Stratagene) and HB101 (Boyer and Roulland-Dussoix, J. Mol. Biol., 41 (1969), 459; Bolivar and Backman, Messages Enzymol. 68 (1979), 2040) are maintained and cultured by using standard E. coli culture media (Sambrook, supra).

c. Construction of cefE expression cassettes

The cefE expression cassettes are listed in Table I, which also explains the nomenclature that has been used for these plasmids.

Table I
List of cefE expression cassettes that were constructed

Legends:
[1]tac = trp-lac hybrid promoter
[2]gpd = 5′-end of A. nidulans gpdA gene
[3]AT = 3′-end of P. chrysogenum penDE gene
[4]AT = 5′-end of P. chrysogenum penDE gene

Plasmid	Promoter	Gene	Microbody targeting	Terminator
pMCTSE	tac[1]	S.cla cefE		FdT
pMCTNE	tac	N.lac cefE		Fdt
pGSE	gpd[2]	S.cla cefE		-
pGNE	gpd	N.lac cefE		-
pGNETA	gpd	N.lac cefE	+ target	AT[3]
pGNEWA	gpd	N.lac cefE	Wt	AT
pANETA	AT[4]	N.lac cefE	+ target	AT
pANEWA	AT	N.lac cefE	Wt	AT
pGSETA	gpd	S.cla cefE	+ target	AT
pGSEWA	gpd	S.cla cefE	Wt	AT
pASETA	AT	S.cla cefE	+ target	AT
pASEWA	AT	S.cla cefE	Wt	AT

Published nucleotide sequences of the S. clavuligerus cefE gene (Kovacevic, supra); the N. lactamdurans cefE gene (Coque, supra); the A. nidulans gpdA gene (Punt et al., Gene 69 (1988), 49-57); and the P. chrysogenum penDE gene (Barredo et al., Gene 83 (1989), 291-300; Diez et al., Mol. Gen. Genet. 218 (1989), 572-576) have been used to design synthetic oligonucleotides listed in Table II.

Table II

Oligonucleotides used in the construction of a P. chrysogenum expression cassettes for the N. lactamdurans and the S. clavuligerus cefE gene

1. 5'-GCT GAA GGA GCT GAG CAT ATG ACG
   GAC GCG ACC GTG CCG ACC-3'
2. 5'-CCC GGG TCT AGA TCT AGA TCA CCG
   GGC GGC GGC GGT CTT CCG GAT GTT-3'
3. 5'-GAT CAG TGA GAG TTG CAT ATG GAC
   ACG ACG GTG CCC ACC TTC AGC CTG-3'

../..

4. 5′-CCC GGG TCT AGA TCT AGA CTA TGC CTT GGA TGT GCG GCG GAT GTT-3′

5. 5′-GAG CTC TGT GAA TTC ACA GTG ACC GGT GAC TCT TTC-3′

6. 5′-GGG AGC CAT ATG GAT GTC TGC TCA AGC GGG GTA GCT-3′

7. 5′-AGA ACG GAT TAG TTA GTC TGA ATT CAA CAA GAA CGG CCA GAC-3′

8. 5′-GAC AGA GGA TGT GAA GCA TAT GTG CTG CGG GTC GGA AGA TGG-3′

9. 5′-ACA TCA ACA TCC GGA AGA CCG CCG CCG CCC GGT GAA GGC TCT TCA TGA-3′

10. 5′-GGA CTA GTG TCG ACC CTG TCC ATC CTG AAA GAG TTG-3′

11. 5′-ACA TCA ACA TCC GGA AGA CCG CCG CCG CCC GGC TTT GAA GGC TCT TCA-3′

12. 5′-TTC GAT GTC AGC CTG GAC GGC GAG ACC GCC ACG TTC CAG GAT TGG ATC GGG GGC AAC TAC GTG AAC ATC CGC CGC ACA TCC AAG GCA TGA AGG CTC TTC ATG ACG-3′

13. 5′-GAT GTC AGC CTG GAC GGC GAG ACC GCC ACG TTC CAG GAT TGG ATC GGG GGC AAC TAC GTG AAC ATC CGC CGC ACA TCC AAG CTA TGA AGG CTC TTC ATG ACG-3′

c1. Construction of the E. coli cefE expression plasmids pMCTSE and pMCTNE

PCR, 1: N. lactamdurans cefE

In a first PCR using chromosomal DNA of N. lactamdurans and oligonucleotides 1 and 2, the N. lactamdurans cefE open reading frame was obtained as a 0.9 kb PCR product, containing a unique NdeI restriction site at the 5′-end and a unique XbaI site at the 3′-end.

PCR, 2: S. clavuligerus cefE

In a second PCR using chromosomal DNA of S. clavuligerus and oligonucleotides 3 and 4, the S. clavuligerus cefE open reading frame was obtained as a 0.9 kb PCR product, also containing a unique NdeI restriction site at the 5'-end and a unique XbaI restriction site at the 3'-end.

For the purpose of obtaining expression of the cefE genes in E. coli and characterisation of the PCR products by DNA sequence analysis, PCR products 1 and 2 were cloned in the vector pMCTNde, a derivative of pMC-5 (Stanssens et al., Nucleic Acids Res. 17 (1989), 4441). Plasmid pMCTNde was derived from pMC5-8 (European patent application No. 0351029) by insertion of a fragment encoding the tac promoter followed by a RBS site and a NdeI cloning site (figure 3).

PCR products 1 and 2 were digested with NdeI and XbaI and ligated into NdeI-XbaI digested vector pMCTNde. The ligation mixture was used to transform E. coli WK6. Transformants were selected for resistance to chloramphenicol. These transformants are used to isolate plasmid DNA. The cefE expression cassette insert is first analyzed by restriction enzyme digestion on the predicted generation of restriction fragments. Plasmids containing the predicted restriction enzyme sites are finally analyzed by automated DNA sequence analysis.

The DNA sequence of the S. clavuligerus cefE open reading frame in plasmid pMCTSE (figure 2) was 100% identical to the published sequence (Kovacevic, supra).

The DNA sequence (figure 8) of all the clones that were analyzed, containing the N. lactamdurans cefE open reading frame, was different from the published sequence (Coque, supra).

The derived amino acid sequence of the published N. lactamdurans cefE gene has a proline at amino acid position 41 (see Seq.ID No. 14). This proline is missing in the clones that were obtained in PCR 1. This plasmid is called pMCTNE (figure 1).

c2. Construction of the P. chrysogenum cefE expression plasmids

PCR, 3: gpdA promoter

In this third PCR, using pAN7-1 plasmid DNA (Punt et al., Gene 56 (1987), 117-124), containing the E. coli hph gene under control of the A. nidulans gpdA promoter and oligonucleotides 5 and 6, the gpdA promoter was obtained as a 0.9 kb PCR product containing a unique EcoRI restriction site at the 5'-end and a unique NdeI site at the 3'-end.

PCR, 4: AT promoter

In the fourth PCR chromosomal DNA of P. chrysogenum and oligonucleotides 7 and 8 were used to obtain an AT promoter fragment of 1.5 kb, that also contains a unique EcoRI restriction site at the 5'-end and a unique NdeI site at the 3'-end.

PCR, 5: AT terminator and 3'-end of N. lactamdurans cefE gene

In a fifth PCR a 0.5 kb penDE (AT) terminator region was obtained using chromosomal DNA of P. chrysogenum and oligonucleotides 9 and 10, and 11 and 10, respectively. These PCR products thus contain the 3'-terminal sequence of the cefE gene with or without a microbody targeting signal, consisting of a C-terminal amino acid sequence ARL (Müller et al., Biochimica et Biophysica Acta 1116 (1992), 210-213).

The oligonucleotides are designed in such a way that a unique BspEI site is introduced at the 5'-end of the PCR product and a unique SpeI site is introduced at the 3'-end of the PCR product.

PCR, 6: AT terminator and 3'-end of S. clavuligerus cefE gene

In this sixth PCR the 0.5 kb penDE (AT) terminator region was obtained using chromosomal DNA of P. chrysogenum and oligonucleotides 12 and 10, and 13 and 10, respectively. These PCR products thus contain the 3'-terminal sequence of the S. clavuligerus cefE gene with or without a microbody targeting signal, consisting of a C-terminal amino acid sequence SKL (De Hoop et al., Biochem. J. 286 (1992), 657-669).

The oligonucleotides are designed in such a way that a unique BglI restriction site is introduced at the 5'-end of the PCR product and a unique SpeI site is obtained at the 3'-end of the PCR product.

For the purpose of obtaining expression of the cefE genes in P. chrysogenum the gpdA promoter and the AT promoter fragment were ligated to the cefE fragments from the plasmids pMCTNE and pMCTSE. These ligated fragments were cloned into the vector pBluescript II KS.

PCR 3 was digested with EcoRI and NdeI. pMCTNE and pMCTSE were digested with NdeI and XbaI. The restriction fragments were separated by agarose gel electrophoresis. The 0.9 kb cefE coding fragments were purified from the agarose gel. The EcoRI-NdeI promoter fragment was ligated together with the NdeI-XbaI cefE fragments into EcoRI-XbaI digested vector pBluescript II KS. Thus the following plasmids were obtained: pGSE and pGNE.

To obtain optimal expression of the cefE genes in P. chrysogenum we chose to clone the AT termination signal sequence behind the cefE genes in the Penicillium expression plasmids mentioned above.

pGNETA-pGNEWA

PCR 5 products were digested with BspEI and SpeI and ligated into BspEI and SpeI digested vector pGNE. Ligation mixtures were used to transform E. coli HB101. Transformants were selected for resistance to ampicillin. Plasmids isolated from these transformants were characterized by restriction fragment analysis and later by DNA sequence analysis. Thus the following plasmids were obtained: pGNEWA and pGNETA (figure 4).

pGSETA-pGSEWA

PCR 6 products were digested with BglI and SpeI and ligated into BglI and SpeI digested vector pGSE. Ligation mixtures were used to transform E. coli HB101. Transformants

were selected for resistance to ampicillin. Plasmids isolated from these transformants were also characterized by restriction fragment analysis and later by DNA sequence analysis. Thus the following plasmids were obtained: pGSEWA and pGSETA (figure 5).

pANETA, pANEWA and pASETA and pASEWA

The plasmids pGNETA, pGNEWA, pGSETA and pGSEWA were digested with EcoRI and NdeI. The restriction fragments were separated by agarose gel electrophoresis and the 4.5 kb fragments were purified from the gel.

PCR 4 product was digested with EcoRI and NdeI and ligated with the purified fragments mentioned above. After transformation of the ligation mixtures into E. coli HB101, transformants were selected for ampicillin resistance.

Transformants were grown and their plasmids were isolated and characterized by restriction fragment analysis and finally DNA sequence analysis. Thus the desired constructs were obtained, viz. pANETA (figure 6), pANEWA, pASETA (figure 7) and pASEWA.

d. Transformation of P. chrysogenum

The Ca-PEG mediated protoplast transformation procedure is used.

Following the procedures described in Cantoral (vide supra), Gouka et al. (J. Biotechn., vide supra) and Gouka et al. (Appl. Microbiol. Biotechnol.,vide supra) total plasmid or the purified cefE expression cassette (devoid of E. coli vector sequences) was used to transform strains of P. chrysogenum with the pyrG, niaD, facA or amdS (Beri et al., Curr. Genet. 11 (1987), 639-641) genes, respectively, as selection markers.

By using the homologous pyrG, niaD or facA selection markers in purified form, devoid of E. coli vector sequences, transformed P. chrysogenum strains were obtained which do not contain bacterial resistance genes.

European patent application No. 94201896.1 describes a method for obtaining selection marker gene free recombinant strains.

This method was successfully used on P. chrysogenum transformants containing the A. nidulans amdS gene as a dominant selection marker.

The only elements of heterologous nature then, are the 0.9 kb cefE coding region, and, optionally, the 0.9 kb gpdA promoter region.

e. Analysis of transformants

P. chrysogenum transformants are purified by repeated cultivation on selective medium. Single stable colonies are used to prepare agar slants to produce spores and to screen for transformants containing the cefE expression cassette. Boiling a fragment of fresh mycelium from transformants on an agar plate was used to obtain enough template DNA to efficiently screen hundreds of transformants for the presence of the cefE gene using the PCR technique. (Seth, Fungal Genetics Conference, Asilomar (1991), abstract in Fungal Genetics Newsletter 38, 55.) By doing so efficiency of transformation was estimated.

Screening of transformants was also done using a bio-assay. Transformants were grown on agar medium that contained the side-chain precursor of choice. E. coli ESS2231 was used as indicator bacterium in an agar overlay, that also contained Bacto penase to be able to discriminate between penicillin and cephalosporin production according to methods well known in the art and described for example in Guttiérez et al., Mol. Gen. Genet. 225 (1991), 56-64).

Spores are used to inoculate P. chrysogenum culture medium as described in section d. After 72 hours of cultivation (at 25°C) chromosomal DNA is isolated from the mycelium. The DNA is digested with a restriction enzyme with a 6 bp recognition sequence like EcoRI or PstI.

The DNA fragments are separated by agarose gel electrophoresis and blotted onto Gene screen nylon membranes (New England Nuclear). The Southern blots are hybridized with the ^{32}P labelled PCR 2 product as a probe for cefE gene sequences. ^{32}P labelling of purified PCR 2 product is achieved by random priming labelling

in the presence of $\alpha^{32}P$ dCTP by using a commercial labelling kit (Boehringer Mannheim).

Transformants containing the cefE coding sequence are tested for expression of the cefE gene product, here referred to as expandase activity.

Selected transformants are cultivated in penicillin production medium (see Example 2).

In a time-course experiment, mycelium samples are taken after 48, 72 and 96 hours of fermentation. Mycelial extracts are prepared and expandase activity is determined in crude extracts essentially as described in Rollins et al., Can. J. Microbiol. 34 (1988), 1196-1202. Transformants with expandase activity are tested for acyltransferase activity as well by the methods described in Alvarez et al., Antimicrob. Agent Chem. 31 (1987), 1675-1682).

From these analyses transformants with different levels of acyltransferase and expandase enzymatic activities are selected for fermentative production of 7-ADCA derivatives.

Example 2

Fermentative production of 3-(carboxyethylthio)propionyl-7-ADCA and isolation of the same

P. chrysogenum strain Wisconsin 54-1255 (ATCC 28089) is transformed with one of the DNA constructs as described in Example 1 and inoculated at 2 * 10^6 conidia/ml into a seed medium consisting of (g/l): glucose, 30; $(NH_4)_2SO_4$, 10; KH_2PO_4, 10; trace element solution I ($MgSO_4.7H_2O$, 25; $FeSO_4.7H_2O$, 10; $CuSO_4.5H_2O$, 0.5; $ZnSO_4.7H_2O$, 2; Na_2SO_4, 50; $MnSO_4.H_2O$, 2; $CaCl_2.2H_2O$, 5), 10 (ml/l) (pH before sterilization 6.5).

The seed culture is incubated for 48-72 hours at 25-30°C and subsequently used to inoculate 10-20 volumes of a production medium containing (g/l) lactose, 80; maltose, 20; $CaSO_4$, 4; urea, 3; $MgSO_4.7H_2O$, 2; KH_2PO_4, 7; NaCl, 0.5; $(NH_4)_2SO_4$, 6; $FeSO_4.7H_2O$, 0.1; 3,3'-thiodipropionic acid, 5; trace element solution II ($CuSO_4.5H_2O$, 0.5; $ZnSO_4.7H_2O$, 2; $MnSO_4.H_2O$, 2; Na_2SO_4, 50), 10 (ml/l)

(pH before sterilization 5.5-6.0). The incubation is then continued for another 96-120 hours.

At the end of the production fermentation the mycelium is removed by centrifugation or filtration and 3-(carboxyethylthio)propionyl-7-ADCA are analyzed by high performance liquid chromatography (HPLC) on a reversed-phase column. The HPLC apparatus used is a Beckman System Gold, consisting of a model 126 programmable solvent system, a model 507 autosampler, a model 168 diode-array detector and System Gold data system (5.10). As the stationary phase two (2) Chromspher C18 cartridge columns (100 x 3 mm, Chrompack) in series are used. The mobile phase consists of a linear gradient from 100% 0.07M phosphate buffer pH 4.8 to 25% acetonitrile and 75% phosphate buffer pH 4.8 in 15 minutes at a flow rate of 0.5 ml/min. The production of 3-(carboxyethylthio)propionyl-7-ADCA is quantitated at 260 nm using synthetic 3-(carboxyethylthio)propionyl-7-ADCA as reference substance.

The peak identity is confirmed by comparison of the on-line UV and NMR spectra.

After filtering of the broth about 0.1 volume of 1-butanol is added to the filtrate. The pH value is adjusted to 2 with diluted hydrochloric acid and the mixture is stirred for 5 minutes at room temperature. After separation, the organic layer is either evaporated and further used in the chemical deacylation (example 3) or back-extracted with 0.33 volume of water of pH 8 and used further in the enzymatic deacylation (example 4).

Example 3

Deacylation of 3-(carboxyethylthio)propionyl-7-ADCA

To a mixture of 3 g (8 mmoles) 3-(carboxyethylthio)propionyl-7-ADCA, 3.5 ml (36 mmoles) of N,N-dimethylaniline, 13 ml of methylene chloride, and 2.6 ml (21 mmoles) of trimethylchlorosilane is added at ambient temperature. After stirring for 30 minutes the reaction mixture is cooled to about -50°C and 1.8 g (8.5 mmoles) of phosphorus pentachloride is added all at once.

The temperature is maintained at -40°C for two hours and subsequently the reaction mixture is cooled to -65°C. It is then treated with 12 ml (137 mmoles) of isobutanol at such a rate that the temperature does not rise above -40°C. After additional stirring for two hours, the solution is poured in 15 ml of water, and 5 ml of 4.5 N ammonia is added immediately afterwards. The pH is adjusted to 4 by slow addition of solid ammonium bicarbonate. After cooling to 5°C the mixture is filtered, the crystalline 7-ADCA is washed with 5 ml of aqueous acetone (1:1) and isolated.

Example 4

Enzymatic deacylation of 3-(carboxyethylthio)propionyl-7-ADCA using a mutant of Pseudomonas SY77 acylase

The conversion of 3-(carboxyethylthio)propionyl-7-ADCA is carried out in a single enzymatic step using a specific acylase which has been derived from Pseudomonas SY77 acylase via region directed mutagenesis. The construction and identification of the mutant Pseudomonas SY77 acylase with improved activity towards the 3-(carboxyethylthio)propionyl side chain has been described in EP-A-0453048. In the mutant the tyrosine at position 178 in the α-subunit of the Pseudomonas SY77 acylase has been replaced by histidine. The mutant acylase is produced in E. coli. Cells are harvested by centrifugation and resuspended in 10 mM phosphate buffer pH 7.4 containing 140 mM NaCl. Subsequently the cells are disrupted by sonification. After removing the cell debris the supernatants containing the acylase activity are collected. Further purification of the acylase is performed by a series of chromatographic steps: (1) ion-exchange chromatography on Q-sepharose fast-flow at pH 8.8; (2) hydrophobic interaction chromatography on Phenyl-Sepharose; and (3) gel-permeation chromatography on a Sephacryl S200HR column.

The purified acylase is immobilized onto particles consisting of a mixture of gelatine and chitosan. The particles are treated with glutaraldehyde just before addition of the enzyme.

The conversion of 3-(carboxyethylthio)propionyl-7-ADCA is carried out in a stirred tank reactor. First the aqueous

cephalosporin solution is added to the reactor. Subsequently the temperature of the solution is brought to 30°C at constant stirring and the pH is fixed at 8 with potassium hydroxide. Then the immobilized enzyme is added and the conversion starts. During the conversion the pH in the reactor is recorded continuously and kept at 8. The 3,3'-thiodipropionic acid which is liberated during the reaction is titrated with KOH. The amount of KOH which is added is integrated and recorded on a flatbed recorder. The conversion is monitored by collecting samples from the reactor which are analyzed for 3-(carboxyethylthio)propionyl-7-ADCA and 7-ADCA by HPLC as described in Example 2.

When the reaction is completed the immobilized enzyme is removed by filtration and the pH of the filtrate is brought to 1 while the filtrate comprises butyl acetate. The layers are separated and the pH of the aqueous phase which contains 7-ADCA is adjusted to 3. The crystalline 7-ADCA is then filtered off.

Example 5

Enzymatic deacylation of 3-(carboxyethylthio)propionyl-7-ADCA using Pseudomonas SE83 acylase

The conversion of 3-(carboxyethylthio)propionyl-7-ADCA is carried out as in example 4, however, under the application of Pseudomonas SE83 acylase as acylase, yielding the same result.

Claims

1. A process for the preparation and recovery of 7-amino-desacetoxycephalosporanic acid (7-ADCA) by:

a) transforming a Penicillium chrysogenum strain with an expandase gene, under the transcriptional and translational regulation of filamentous fungal expression signals;

b) fermenting said strain in a culture medium and adding to said culture medium 3,3'-thiodipropionic acid or a salt or ester thereof suitable to yield 3-(carboxyethylthio)propionyl-6-aminopenicillanic acid (3-(carboxyethylthio)propionyl-6-APA), which are in situ expanded to form 3-(carboxyethylthio)propionyl-7-ADCA;

c) recovering the 3-(carboxyethylthio)propionyl-7-ADCA from the fermentation broth;

d) deacylating said 3-(carboxyethylthio)propionyl-7-ADCA; and

e) recovering the crystalline 7-ADCA.

2. A process according to claim 1 wherein said Penicillium chrysogenum strain is transformed with an expandase gene, under the transcriptional and translational regulation of the expression signals of the AT gene.

3. A process according to claim 1 or 2, wherein step (e) is a filtration step.

4. A process according to anyone of the preceding claims, wherein step (c) is a filtration step, and by extracting the broth filtrate with an organic solvent immiscible with water at a pH of lower than about 4.5 and back-extracting the same with water at a pH between 4 and 10.

5. A process according to anyone of the preceding claims wherein the expandase gene is derived from Streptomyces clavuligerus or Nocardia lactamdurans.

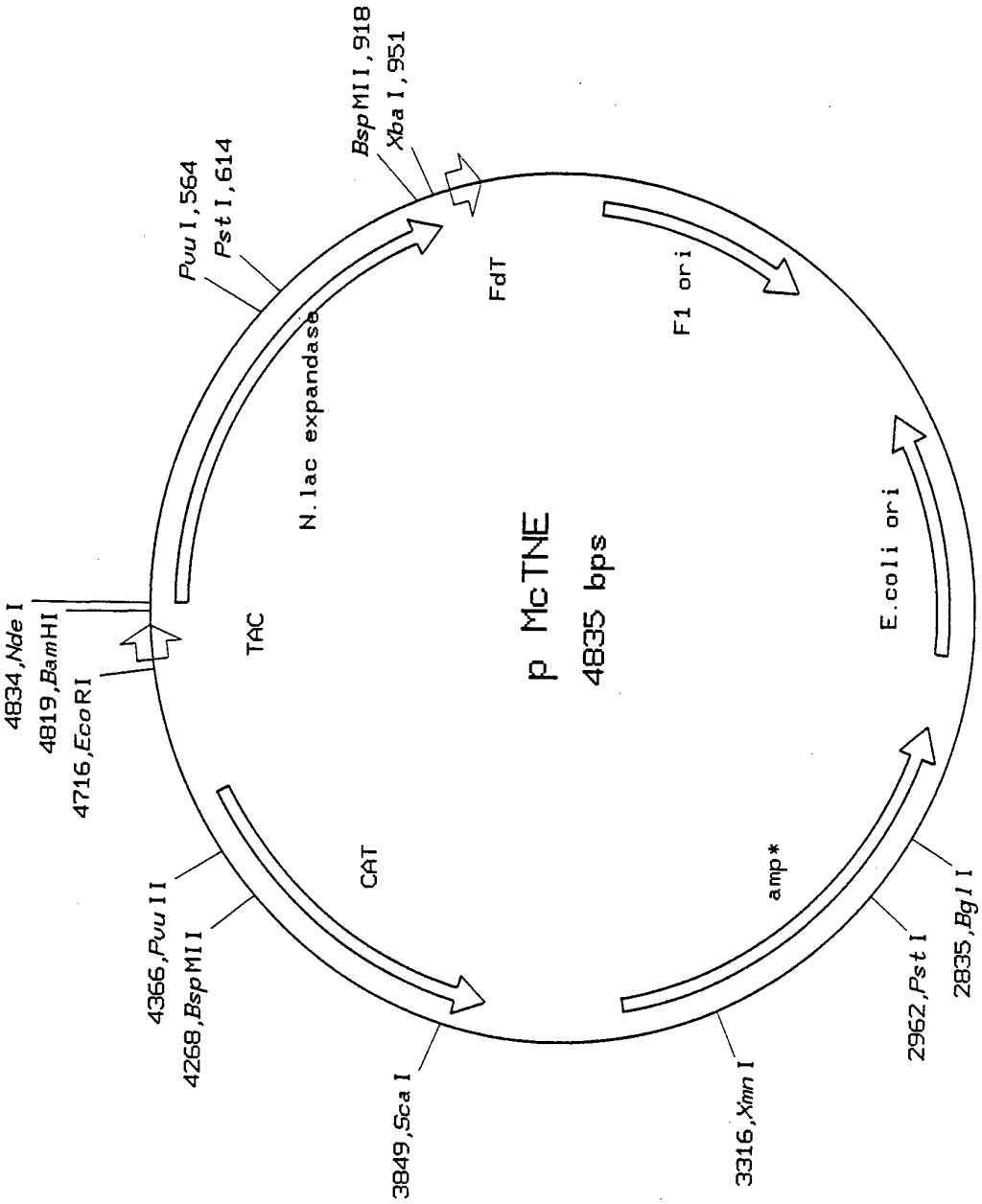
6. A recombinant DNA vector comprising the DNA encoding expandase, functionally linked to the transcriptional and translational regulation of filamentous fungal expression signals.

7. A recombinant DNA vector according to claim 6 wherein the DNA encoding expandase is functionally linked to the transcriptional and translational regulation of the expression signals of the AT gene.

8. A recombinant DNA vector according to claim 6 or 7 wherein the DNA encoding expandase has been derived from Streptomyces clavuligerus or Nocardia lactamdurans.

9. A host cell transformed with a vector defined in any one of the claims 6, 7 or 8.

FIG. 1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PvuI, 564
PstI, 614
4834, NdeI
4819, BamHI
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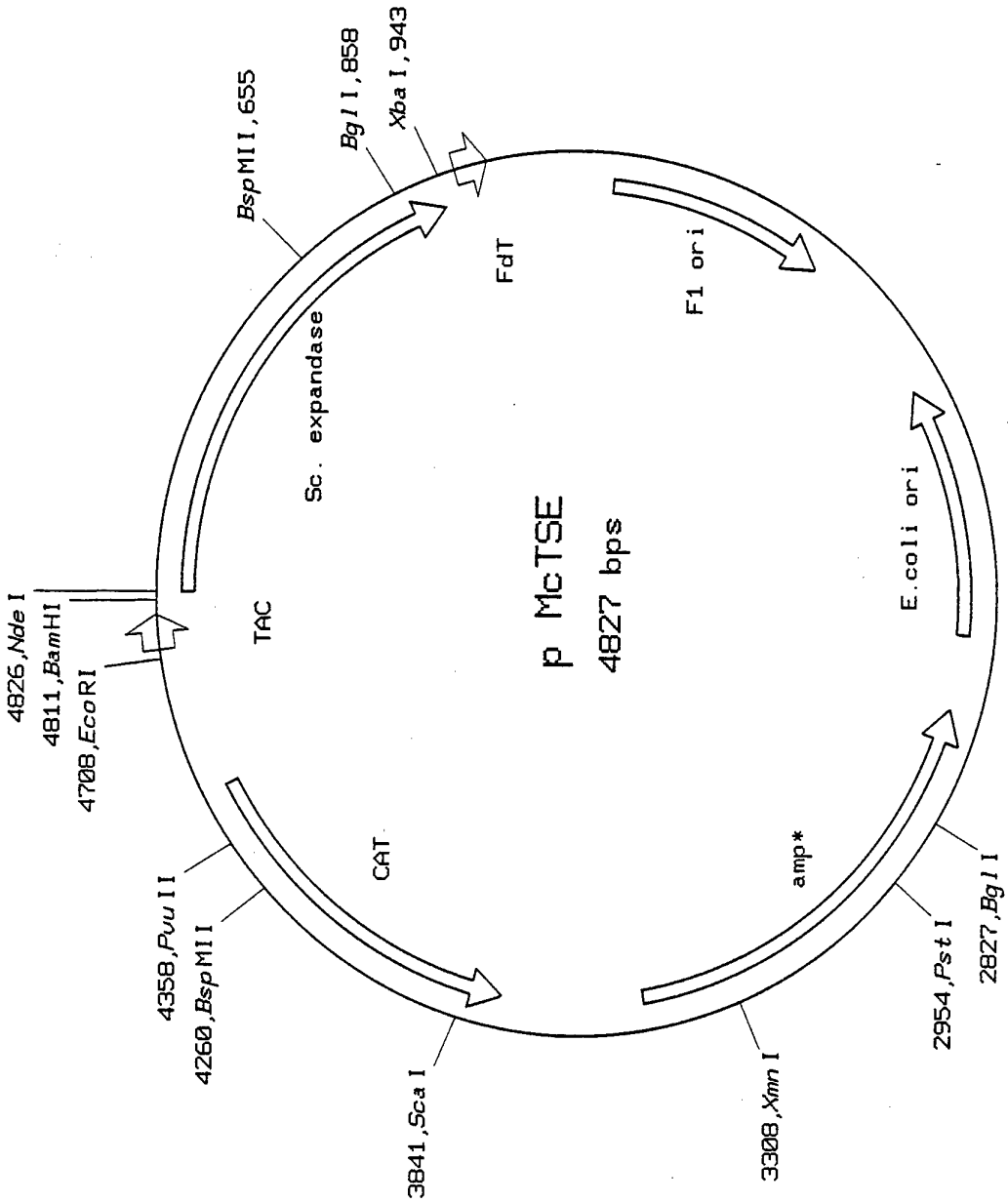
2835, BglI

Fig.2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amp*
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4811,BamHI
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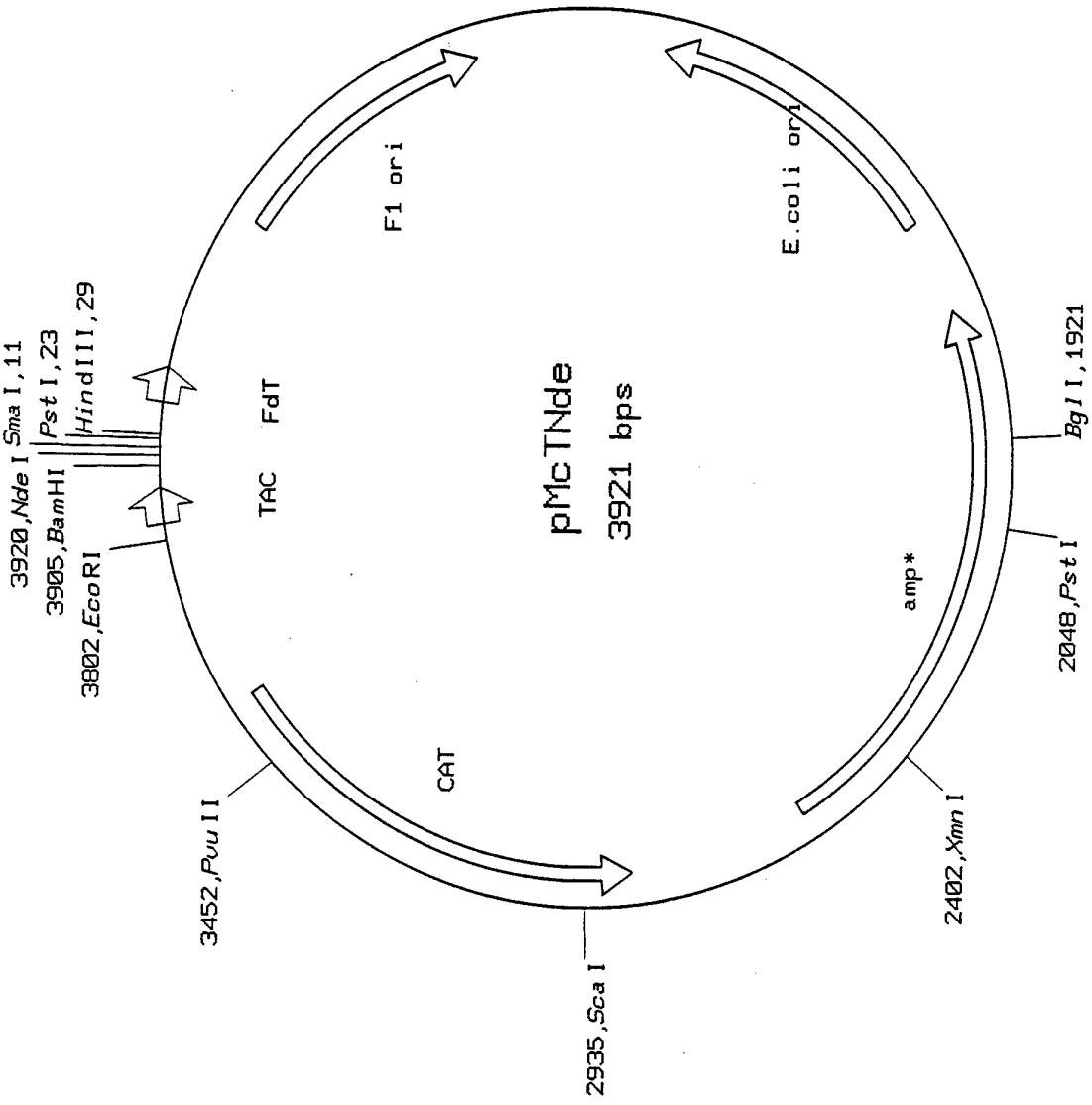
2827,BglI

FIG. 3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E.coli ori
TAC
FdT
CAT
amp*
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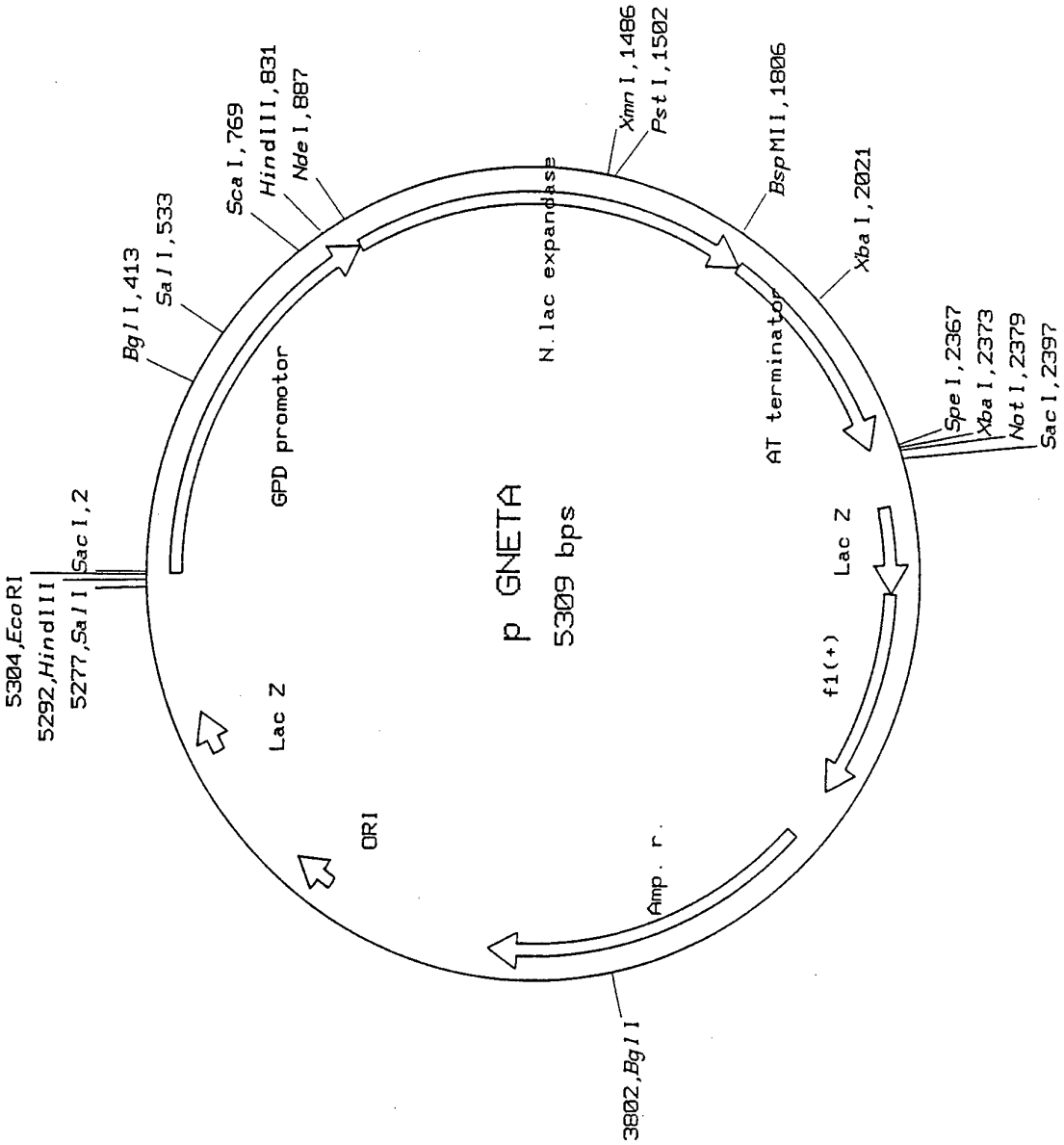
2935,Sca I
2402,Xmn I
2048,Pst I
Bgl I,1921

FIG. 4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Lac Z
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ORI
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Sal I, 533
Sca I, 769
HindIII, 831
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Xba I, 2021
Spe I, 2367
Xba I, 2373
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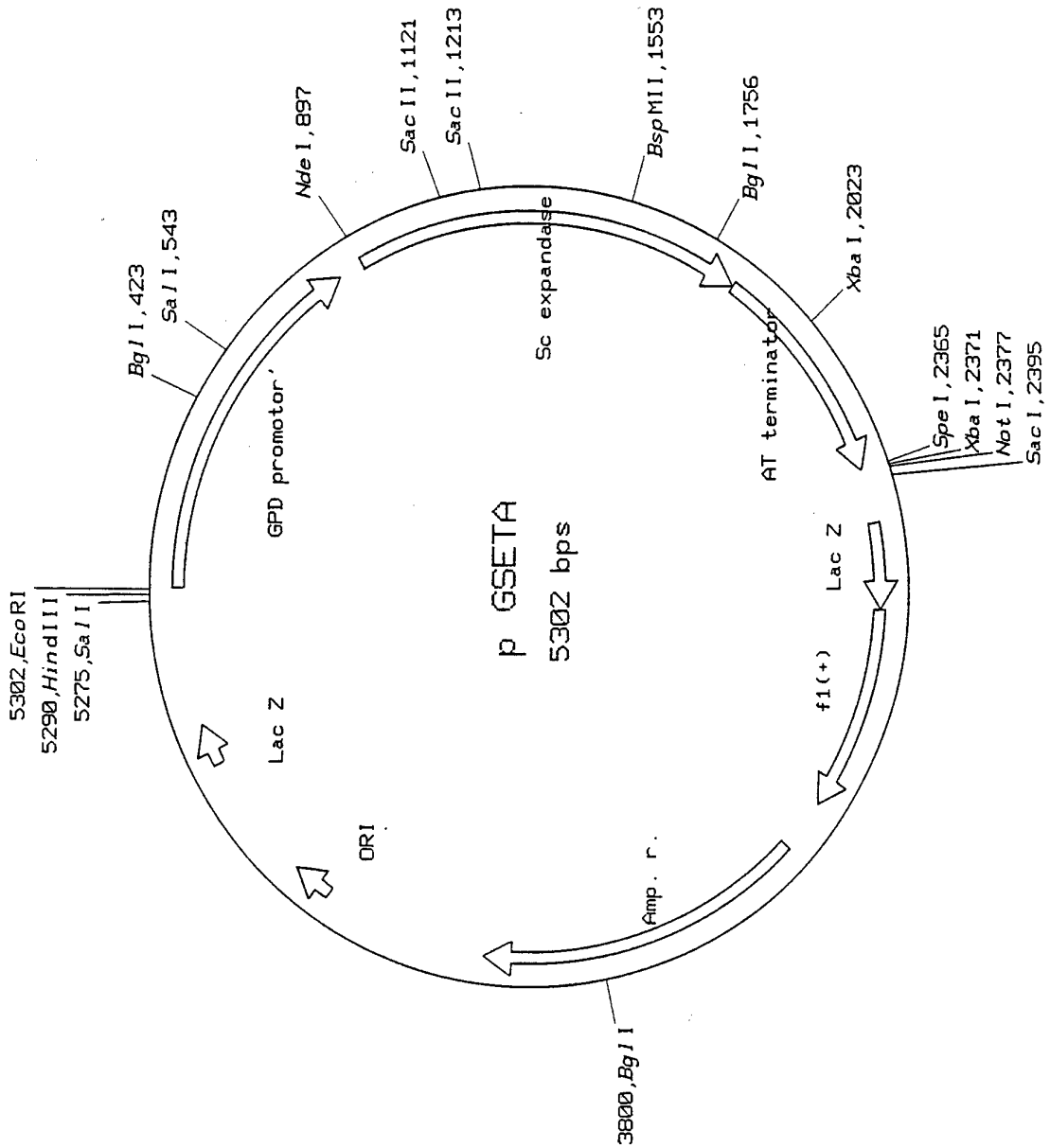
5277, Sal I
Sac I, 2
3802, Bgl I

Fig. 5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ORI
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Sac II, 1213
BspMII, 1553
Bgl I, 1756
Xba I, 2023
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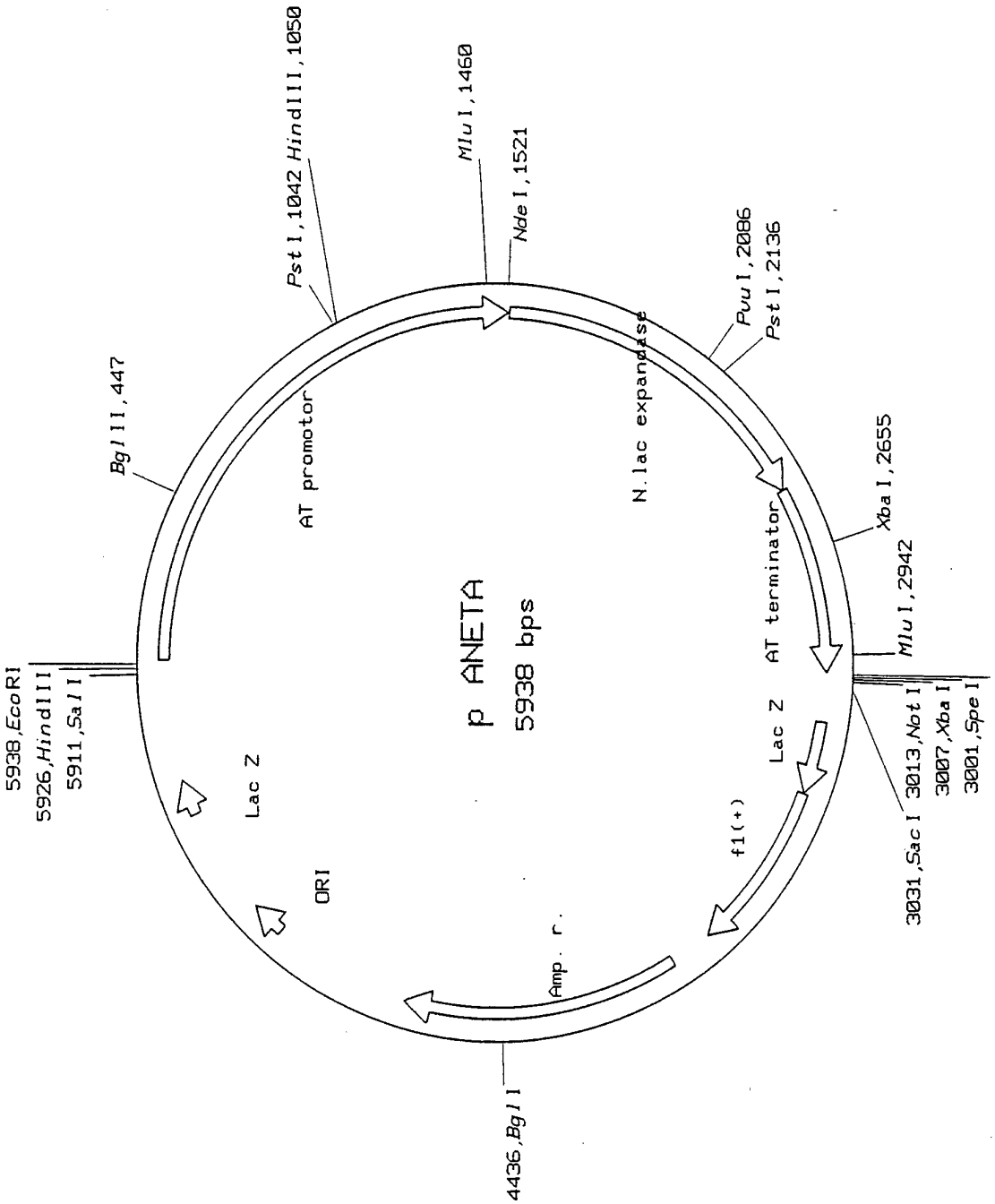
5275, Sal I
3800, Bgl I

Fig. 6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Pvu I, 2086
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Mlu I, 2942
3013, Not I
3007, Xba I
3001, Spe I
3031, Sac I
4436, Bgl I
Bgl II, 447
5938, EcoRI
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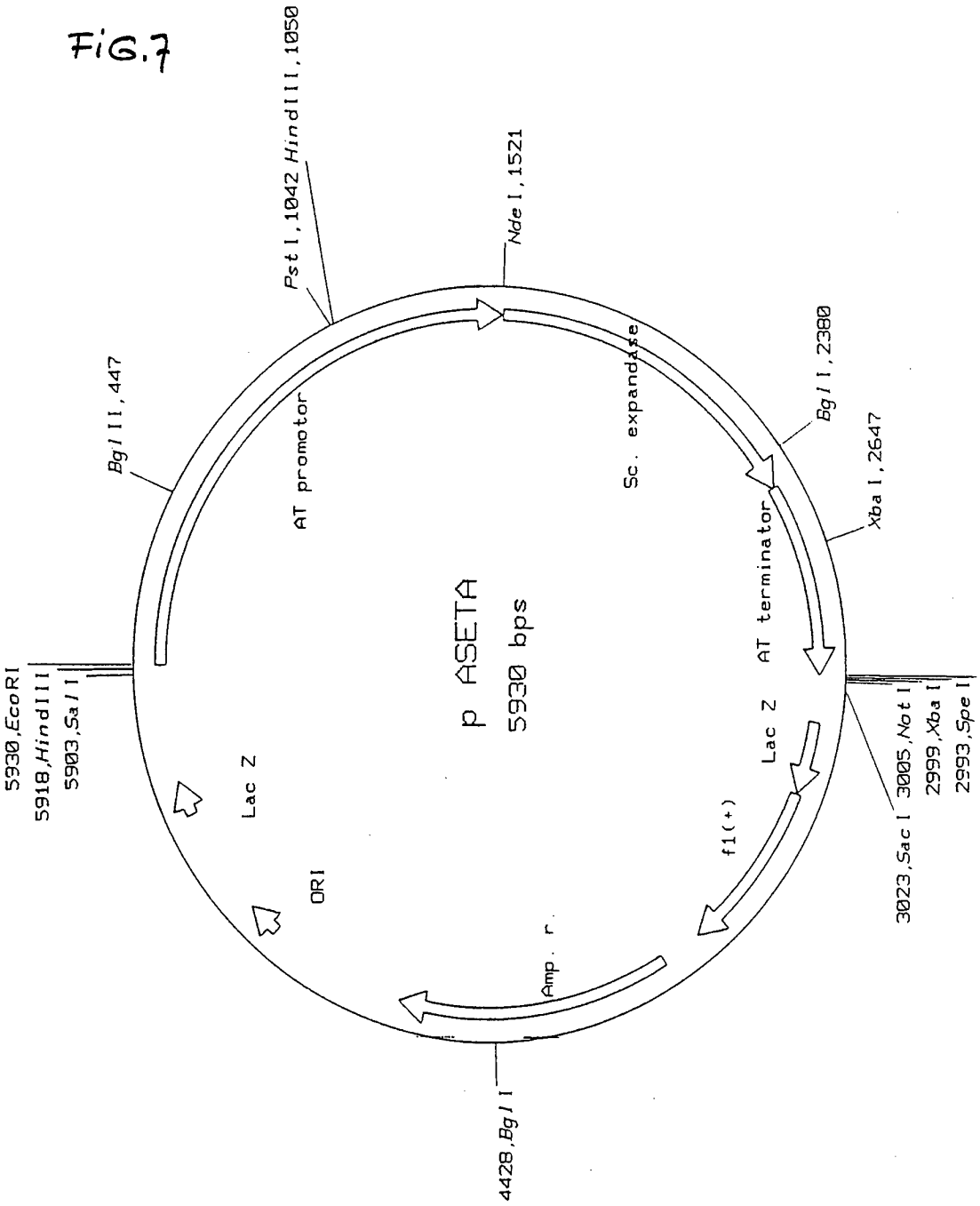
N. lac expandase
AT terminator
Lac Z
f1(+)
Amp. r.
ORI
Lac Z

FIG.7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Sc. expandase
AT terminator
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5930 bps
5930, EcoRI
5918, Hind III
5903, Sal I
Lac Z
Lac Z
ORI
f1(+)
Amp. r
3023, Sac I
3005, Not I
2999, Xba I
2993, Spe I
4428, Bgl II

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1       ATGACGGACGCGACCGTGCCGACCTTCGATCTGGCCGAGCTGCGTGAGGGCTTGCACCAG

61      GAGGAGTTCCGCCACTGCCTGCGCGAGAAGGGCGTGTTCTACCTCAAGGGCACCGGGCT
61      GAGGAGTTCCGCCACTGCCTGCGCGAGAAGGGCGTGTTCTACCTCAAGGGCACCGGGCTG

120     C G CCGAGGCGGACCACGGCTCGGCGCGGGAGATCGCGGTGGACTTCTTCGACCACGGC
121     CCGGCCGAGGCGGACCACGGCTCGGGCCGGGAGATCGCGGTGGACTTCTTCGACCACGGC

178     ACCGAGGCCGAGAAGAAGGCGGTGATGACGCCGATCCCGACCATCCGGCGCGGGTACGCC
181     ACCGAGGCCGAGAAGAAGGCGGTGATGACGCCGATCCCGACCATCCGGCGCGGGTACGCC

238     GGGCTGGAGTCCGAGAGCACCGCGCAGATCACGAACACCGGCAAGTACACCGACTACTCG
241     GGGCTGGAGTCCGAGAGCACCGCGCAGATCACGAACACCGGCAAGTACACCGACTACTCG

298     ATGTCGTACTCGATGGGCACCGCGGACAACCTGTTCCCCAGCGCCGAGTTCGAGAAGGCG
301     ATGTCGTACTCGATGGGCACCGCGGACAACCTGTTCCCCAGCGCCGAGTTCGAGAAGGCG

358     TGGGAGGACTACTTCGCGCGGATGTACCGCGCTTCGCAGGACGTCGCGCGGCAGGTGCTG
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418     ACCTCGGTCGGCGCGGAACCCGAGGTCGGCATGGACGCCTTCCTCGACTGCGAACCCCTG
421     ACCTCGGTCGGCGCGGAACCCGAGGTCGGCATGGACGCCTTCCTCGACTGCGAACCCCTG

478     CTGCGCCTGCGCTACTTCCCCGAGGTGCCCGAGGATCGCGTGGCCGAGGAGCAGCCGCTG
481     CTGCGCCTGCGCTACTTCCCCGAGGTGCCCGAGGATCGCGTGGCCGAGGAGCAGCCGCTG

538     CGGATGGCCCCGCACTAGGACCTCTCGATCGTCACCCTGATCCACCAGACCCCTTGCGCG
541     CGGATGGCCCCGCACTACGACCTCTCGATCGTCACCCTGATCCACCAGACCCCTTGCGCG

598     AACGGGTTCGTCAGCCTGCAGGTCGAGGTGGACGGGTCCTATGTGGACATCCCGGCGCAG
601     AACGGGTTCGTCAGCCTGCAGGTCGAGGTGGACGGGTCCTATGTGGACATCCCGGCGCAG

658     CCGGGCGCGGTGCTGGTGTTCTGCGGCGCGGTGGCGACGCTGGTGGCCGACGGCGCGATC
661     CCGGGCGCGGTGCTGGTGTTCTGCGGCGCGGTGGCGACGCTGGTGGCCGACGGCGCGATC

718     AAGGCGCCCAAGCACCACGTGGCCGCGCCCGGCGCGGACAAGCGGGTGGGCAGCAGCCGC
721     AAGGCGCCCAAGCACCACGTGGCCGCGCCCGGCGCGGACAAGCGGGTGGGCAGCAGCCGC

778     ACCTCCAGCGTGTTCTTCCTGCGCCCCAACGGGGACTTCCGCTTCTCGGTGCCGCGGGCC
781     ACCTCCAGCGTGTTCTTCCTGCGCCCCAACGGGGACTTCCGCTTCTCGGTGCCGCGGGCC

838     AGGGAGTGCGGGTTCGACGTCAGCATCCCGGCCGAGACCGCCACCTTCGACGACTGGATC
841     AGGGAGTGCGGGTTCGACGTCAGCATCCCGGCCGAGACCGCCACCTTCGACGACTGGATC

898     GGCGGCAACTACATCAACATCCGGAAGACCGCCGCCGCCCGG      939
901     GGCGGCAACTACATCAACATCCGGAAGACCGCCGCCGCCCGG      942
```

FIG.8

Matches = 937 Length = 942 Matches/length = 99.5 percent

INTERNATIONAL SEARCH REPORT

International lication No
PCT/EP 94/02544

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12N15/52 C12N1/15 C12N15/80 C12N15/55 C12N9/48
C12P35/00 C12N9/00 //(C12N1/15,C12R1:82,C12R1:19)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12N C12P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 532 341 (MERCK & CO. INC.) 17 March 1993 cited in the application	6,7,9
Y	see the whole document	1-5,8
X	EP,A,0 540 210 (MERCK & CO. INC.) 5 May 1993 cited in the application	6,7,9
Y	see the whole document	1-5,8

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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Date of the actual completion of the international search	Date of mailing of the international search report
29 November 1994	14 -12- 1994

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Espen, J

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MOLECULAR AND GENERAL GENETICS, vol.236, January 1993, BERLIN DE pages 453 - 458 COQUE J. J. R. ET AL. 'Characterization and expression in Streptomyces lividans of cefD and cefE genes from Nocardia lactamdurans: the organization of the cephamycin gene cluster differs from that in Streptomyces clavuligerus' cited in the application see the whole document	6-9
Y	---	1-5
A	EP,A,0 366 354 (ELLY LILLY AND COMPANY) 2 May 1990 cited in the application see the whole document	

A	TETRAHEDRON, (INCL. TETRAHEDRON REPORTS), vol.43, no.13, 1987, OXFORD GB pages 3009 - 3014 BALDWIN J. E. ET AL. 'The enzymatic ring expansion of penicillins to cephalosporins: side chain specificity' see the whole document	

A	NATURE, vol.185, 1960, LONDON GB pages 97 - 99 BALLIO A. ET AL. 'Incorporation of alpha,omega-dicarboxylic acids as side-chains into the penicillin molecule' see the whole document	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International lication No
PCT/EP 94/02544

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0532341	17-03-93	US-A-	5318896	07-06-94
		AU-A-	2354292	18-03-93
		CA-A-	2077921	12-03-93
		CN-A-	1075336	18-08-93
		FI-A-	941135	10-03-94
		NZ-A-	244236	25-03-94
		WO-A-	9305158	18-03-93
EP-A-0540210	05-05-93	AU-A-	2701692	22-04-93
		CA-A-	2080573	16-04-93
		CN-A-	1074484	21-07-93
		FI-A-	941730	14-04-94
		JP-A-	6113884	26-04-94
		NZ-A-	244714	25-03-94
		WO-A-	9308287	29-04-93
EP-A-0366354	02-05-90	US-A-	5082772	21-01-92
		JP-A-	2242675	27-09-90